Appendix H-1

Water Quality and Marine Biological Baseline Studies and Impact Analysis

By Oceanic Institute

Water Quality and Marine Biological Baseline Studies and Impact Analysis
Kona Kai Ola Development, Kailua-Kona, Hawaii

Final Report

Prepared for

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EXECUTIVE SUMMARY

Water quality conditions within Honokohau Harbor, adjacent anchialine ponds and coastal waters of Honokohau Bay are dominated by the effects of groundwater influx. Groundwater quality appears uniform in the region from Wawahiwaa Point to Keahuolu; differences in coastal water quality are the result of differences in bottom bathymetry, nearshore mixing and groundwater influx rates. The greatest impact of groundwater influx was observed on the shallow reef flat north of Honokohau Harbor, offshore of Kaloko Fishpond. Total and dissolved nutrient concentrations were significantly higher at this site than at any other. Concentrations of total and dissolved nutrients at the sites south of Honokohau Harbor were not significantly different. At sites to the south of Honokohau Harbor, the effects of groundwater influx were seen only in stations very close to the shoreline (1 and 10 m) and in shallow samples.

Two anchialine pond complexes are located immediately to the north and south of the Honokohau Harbor entrance channel. The complex to the north is located wholly within the Kaloko-Honokohau National Historical Park; many of the ponds in the southern complex are within the park administrative boundary as well. Ponds in the northern complex show little evidence of anthropogenic impacts: many contain typical vegetation and crustacean species in high abundance. Ponds in the southern complex are moderately to heavily impacted, with many containing exotic fish that exclude the anchialine crustaceans. Ponds also show evidence of human impact: discarded bottles, cans, wrappers, diapers, toilet paper, etc. Water quality conditions within the ponds generally reflect the conditions of the underlying groundwater, with linear relationships between salinity and dissolved nutrients. These data show significant differences in the NO3:Si ratios in the northern and southern pond complexes. Since most ponds in both the northern and southern complexes are vegetated, NO3 uptake is likely to be similar in the two areas. Thus, the data suggest some additional source of NO3 to the ponds in the southern complex, a source which cannot be identified from the available data.

Coral and fish communities within the Honokohau Bay and off the Kona Kai Ola site are generally typical of West Hawaii reefs, with little evidence of anthropogenic impacts. Species composition of corals was typical for Kona reefs, with *Porites lobata* and *Pocillopora meandrina* abundant in the shallow and mid-reef zones, and *Porites compressa* present only in deeper zones. Highest coral abundance was observed at locations immediately to the north and south of the Honokohau Harbor entrance channel. Coral cover at locations north and south of these were not statistically significantly different; however, reefs to the north of Honokohau Harbor in general showed higher coral cover than reefs to the south, primarily because the southern reefs are more exposed to strong surf and associated damage and scour.

Coral communities showed little evidence of negative impact from either general groundwater discharge or from the localized discharge of brackish water from the mouth of Honokohau Harbor. In general, groundwater discharge has no direct impact on coral communities in the Honokohau area because most of the coastline consists of rocky shores with steep shoreline sea cliffs. Water depths at the shoreline are 3 – 5 m, or deeper. Thus, brackish groundwater entering the nearshore zone floats at the surface and rarely comes in contact with deeper corals. The discharge of brackish water from Honokohau Harbor also does not appear to have impacts corals

in the immediate vicinity; in fact, coral abundance is greatest at the two transects located immediately north and south of the entrance channel.

Fish communities appear generally uniform within the study area. No significant differences in number of individuals, number of species, diversity index or biomass were observed between survey sites. Mean numerical abundance of fish was greatest at the deep stations, but mean biomass was highest at the shallow stations.

Major development features that have the potential to impact coastal marine resources include changes in land use from undeveloped barren lava to resort/commercial; changes in coastal ocean use due to increased access and marine-related activities; construction of an expanded harbor; construction of an extensive water feature (lagoon); and use of deep cold ocean water to support air conditioning for the development.

Changes in land use will impact the quality of local groundwater entering the coastal waters of Honokohau Bay and the Kona Kai Ola site. Currently, the site is primarily barren or lightly vegetated recent lava. Rainfall is light, and little water is added to the groundwater resource locally. Very little landscape fertilization takes place, so no nutrients are added to the groundwater. Since there are no developed roadways within the site, no petroleum products or metals are generated on site. After development, extensive landscaping will potentially add both water from irrigation and dissolved nutrients, either form localized fertilizer application of from the use of treated wastewater. Pesticide use is likely to be a general part of landscape maintenance, with the potential for leaching to the groundwater as well.

The impacts of these activities on nearshore coastal communities are likely to be small. Groundwater is less dense than ocean water, and the general discharge of groundwater in the area will tend to float on the surface, separated from the corals located at lease 3 – 5 m below.

Construction of an expanded harbor will have several potentially negative impacts on coastal marine resources. Direct construction impacts are likely to be small. Typical harbor construction is done with a berm separating the construction area from adjacent marine waters, minimizing the discharge of sediment from dredging. A pulse of sediment may be discharged when the berm is removed, but the effects of this type of construction activity are generally localized and temporary.

The presence of the expanded marina will significantly alter the pattern of groundwater flow at the Kona Kai Ola site. Essentially the shoreline will move from its current location to the mauka side of the new harbor. Existing groundwater flows will enter the marina rather than reaching the shoreline, so groundwater discharge through the mouth of Honokohau Harbor will increase significantly. Currently, brackish water discharged from the harbor generally flows to the northwest, along the coastline fronting the Kaloko-Honokohau Park. After construction of the new marina, brackish water flows along the Park coastline will increase.

The expanded harbor will serve as a collection point for materials utilized or generated at the development site, either through direct runoff or by interception of groundwater flow. There is the potential that fertilizers, pesticides, petroleum products, road wastes, etc, could be discharged from the mouth of Honokohau Harbor into the coastal marine environment.

The change in groundwater flow patterns due to construction of the expanded marina will have a significant negative impact on anchialine ponds south of the harbor channel. The ponds in the southern complex will be severely negatively impacted by harbor construction to the extent that any consideration of preservation and/or restoration may be in vain. Construction of the new harbor will significantly alter the pattern of groundwater flow in the area, essentially cutting off the supply of groundwater to the area "downstream" of the harbor. After construction of the new harbor, it is likely the southern ponds will contain essentially full strength sea water (35ppt). The vegetation and animals living in these ponds are sensitive to salinity. Currently, salinity in the majority of the southern ponds is about 14 ppt, or roughly 40% sea water. None of the brackish water vegetation currently in the ponds will likely withstand increased salinity conditions, so one would expect essentially barren ponds some time soon after the harbor is dredged. Since many of the terrestrial plants also depend on subsurface brackish water, most of the trees in the area will die off as well. While the typical anchialine pond crustaceans (the small red shrimp) are tolerant to a wide range of salinity, they are rarely found in ponds with salinity above 25 ppt.

The expanded marina will result in an approximately 4-fold increase in boat traffic and related marine activities, including fishing, scuba diving, dolphin and manta ray watching, snorkeling, dinner cruises, etc. Honokohau Bay is currently the most heavily used area along the Kona coast for diving and water-related activities, due to the presence of Honokohau Harbor, the largest and most heavily used recreational and commercial harbor along the Kona coast. Currently, day-mooring buoys installed by the State of Hawaii in the coastal reach from Keahole Point to Keahuolu are near capacity for the dive operators currently operating out of Honokohau Harbor. During times when heavy surf closes out sections of the coastline, boats from Keauhou Bay will add to the demand, often resulting in either an aborted dive trip or boats anchoring rather than utilizing the day mooring. Increased levels of diving activities as the result of the expanded harbor will overload the existing moorings. Mitigation measures could include the installation of additional moorings.

Water for the lagoons and water features will be pumped from offshore depths of approximately 100 ft through a pipe located at the southern project boundary. Water from this depth is typically low in dissolved nutrients, with concentrations often below the limits of analytical detection. Water will be discharged into the mauka portion of the lagoon and flow makai until it discharges into the new harbor basin. This water will then flow out of the harbor with the lower layer of water typically exchanged with each tidal cycle. Since nutrient concentrations in the discharge are expected to be low, no significant biological impacts to nearby coral communities are foreseen.

Air conditioning for the Kona Kai Ola development may be provided by a system utilizing deep, cold ocean water for cooling (SWAC), as an alternative to conventional air conditioning. Under the current concept plan, the SWAC system would draw about 30 million gallons per day of deep ocean water, and 2 – 3 times that volume warm surface water for AC. After passing through heat exchangers to cool working fluids for the air conditioning system, these flows would be discharged down a separate discharge pipe to depths at which the flow temperature matches ambient temperature. If the water increases by 13 degrees F to 53 F, the discharge depths would be about 250 m. This will eliminate the discharge of nutrients into coastal waters and onto sensitive reefs.

BACKGROUND

Jacoby Development, Inc. (JDI) has been selected to develop Kona Kai Ola at Kealakehe on approximately 530 acres of land at Honokohau, near the Keahole-Kona airport (Figure 1). The development will be located on 200 acres at Honokohau leased from the Department of Hawaiian Homes Land (DHHL) and 330 adjacent acres leased from Department of Land and Natural Resources (DLNR). The Kona Kai Ola project proposes a mixed-use and community-focused marina and resort village. Included in the plan is a 45-acre expanded small boat harbor, including 800 new boat slips; 54 acres of boating facilities, including areas for repair, storage, rental and fueling; about 50 acres of resort timeshare/hotels, including two low-density oceanfront properties, and one medium- and one high-density marine-front property; a marine science center and 23 acres of commercial/retail uses. The development will be built in phases over 14 years or more.

The project site surrounds the existing Honokohau Small Boat Harbor and includes existing harbor-related commercial activities. The site is bounded to the north by the Kaloko-Honokohau National Historical Park and to the south by lands owned by the Queen Liliuokalani Trust. The project will not involve development of the Kaloko-Honokohau National Historical Park or the existing harbor except for the shared entrance channel. The project also includes land to be used for the proposed Kealakehe Parkway extension south through Queen Liliuokalani Trust lands.

Honokohau Harbor was excavated from coastal lavas inland from the shoreline and opened to the sea in March 1970. Environmental studies were conducted in 1971, 1972, 1973 and 1976 to assess the environmental impacts of the harbor construction and presence. Subsequent studies were conducted in 1976 and 1981. The last comprehensive study of conditions within and immediately outside the harbor was conducted in 1991. The results of the benthic community surveys have been presented in Oceanic Foundation, 1975; Maragos, 1983; Maragos, 1991 the results of the marine fish community surveys have been presented in Brock, 1980; Brock, 1983; Brock, 1991.

Kaloko-Honokohau National Historical Park is located on the North Kona cosat of the island of Hawaii, approximately three miles north of the town of Kailua and three miles south of the Keahole Airport. The park area consists of those lands in the ahupua'a of Kaloko and Honokohau makai of the Queen Kaahumanu Highway, a coastal strip extending to Wawahiwaa Point in the ahupua'a of Kohanaiki, and two small parcels located in the ahupua'a of Kealakehe next to the Honokohau small boat harbor. The park also includes the waters of Honokohau Bay. The park was authorized in 1978 by Public Law 95-625 "to provide a center for the preservation, interpretation and perpetuation of traditional native Hawaiian activities and culture…" to be administered in accordance with "provisions of the law generally applicable to the national park system."

OBJECTIVE

The objective of the project was to conduct water quality and aquatic habitat baseline surveys in support of the proposed Kona Kai Ola at Kealakehe (KKO) development. The results of the surveys and impact analyses will be used in support of a Master Development Plan, a Core

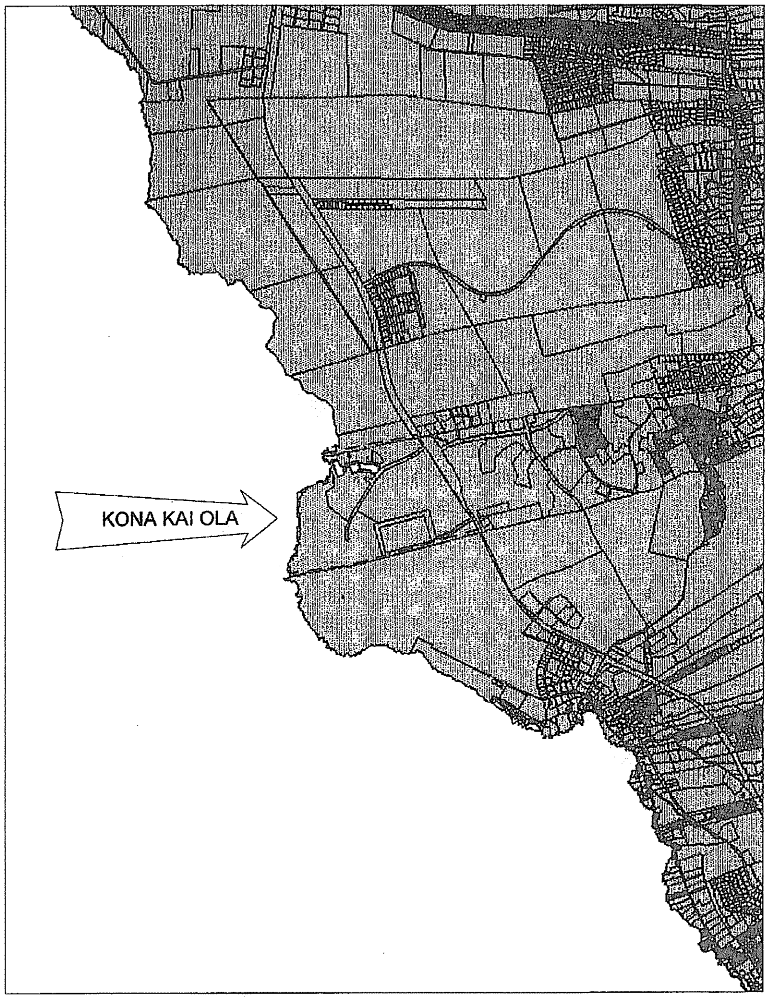

Figure 1. Location of the Kona Kai Ola at Kealakehe project site, Kailua-Kona, Island of Hawaii,

Infrastructure Plan, an Environmental Impact Statement, General Plan Amendment, Change of Zoning Request, Special Management Area Use Permit, Conservation District Use Permit, and Department of the Army Permit.

SCOPE OF WORK

Surveys were conducted to determine the current conditions of water quality and aquatic resources and habitats within and adjacent Honokohau Harbor, the proposed KKO site, and at sites potentially impacted by the proposed KKO development. Potentially-affected aquatic resources and habitats include benthic and fish communities associated with nearshore coral reefs and anchialine ponds and associated organisms. Study efforts included review of historical data for the affected areas, field data collection, data analysis, reporting, discussion and evaluation of potential impacts associated with proposed development activities.

Studies focused on the water quality and biological communities within Honokohau Harbor, in the coastal waters along the Kaloko-Honokohau-Kealakehe coastline, and anchialine ponds onshore. The overall intent of the surveys was to quantitatively describe existing water quality and biological community conditions and to identify potential impacts to these resources due to the proposed development.

The frequency, location and scope of the proposed baseline surveys and analyses were designed to incorporate the current requirements of local and federal permitting agencies, and recognize the sensitive nature of adjacent areas, including the Kaloko-Honokohau Natural Historical Park and numerous popular dive and shoreline fishing sites.

Water Quality

Marine waters of Honokohau Bay (Kaloko Point to Noio Point), included within the boundaries of the Kaloko-Honokohau National Historical Park and offshore of the Kona Kai Ola site to the south of Noio Point are classified "AA" by the State of Hawaii Department of Health. Waters within Honokohau Harbor are classified "A." "A" and "AA" are use classifications; Chapter 54 general water quality standards and numerical criteria are the same for both classes.

Methods

Coastal Water Quality

Water quality conditions along Hawaiian coastlines are influenced by a range of factors, including tidal exchange with oceanic waters, surface discharge from surrounding lands during heavy rainfall events, and continuous discharge of nutrient-laden groundwater. In order to characterize the water quality conditions within Honokohau Harbor and the coastline adjacent the Kona Kai Ola site and to compare these conditions with Chapter 54 water quality criteria, a series of three water quality surveys were conducted within a 14-day period (April 3, 10, 14, 2006).

Water quality surveys were conducted along five transects fronting the shoreline of the project property and adjacent areas (Figure 2). Two transects were located north of the Honokohau Harbor entrance, off the Kaloko-Honokohau National Historical Park; two transects were located south of the harbor entrance between Noio and Kaiwi Points; a fifth control transect was located off Keahuolu. Water samples were collected at distances of 1, 10, 50, 100 and 500 meters from shore. Near surface and near bottom samples were collected at all stations except 1 meter from shore, where only a near-surface sample was collected. Station locations were determined with a hand-held global positioning system unit (GPS; Garmin GPSMAP 76) with position accuracy of 3-5 m. All stations were sampled from a small boat; the 1 and 10 m samples were collected by swimming in from the boat located further offshore. For all stations, near-surface samples were collected at approximately 10 cm below the surface. Water samples were collected directly into polyethylene bottles.

Honokohau Harbor

Water quality surveys were conducted at eight stations within Honokohau Harbor (Figure 3). Near-surface and near-bottom samples were collected at stations 1-4 on April 3 and at stations 5-8 on April 13, 2006. Water samples were collected directly into polyethylene bottles. Near-surface samples were collected at 0.2 m below the surface; near-bottom samples were collected at 0.5 m above the bottom. Samples were analyzed as described below.

Anchialine Ponds

Water quality surveys were performed in anchialine ponds located within or immediately adjacent the project site. A total of twenty-two ponds were located and surveyed to the south of the Honokohau Harbor entrance channel on April 9, 2006, and eighteen ponds to the north were surveyed on April 14, 2006 (Figure 4). Water samples were collected directly into polyethylene bottles. Water quality samples collected contemporaneously with the biological surveys were analyzed as outlined below.

Analytical Procedures

Measurements of temperature, salinity, dissolved oxygen and pH were made immediately after collection with a temperature/salinity/DO meter and a portable pH meter (Table 1). Upon collection, samples were held on ice for shipment to the analytical lab. All analyses were performed by AECOS Labs of Hawaii (Kona, Hawaii). Upon receipt at the lab, subsamples of each sample were filtered for determination of total suspended solids and chlorophyll. The filtrate was analyzed for total dissolved nitrogen (TDN) and total dissolved phosphorus (TDP), nitrate+nitrite-nitrogen (NO_3-N), ammonia-nitrogen (NH_4-N), reactive phosphate (PO_4-P) and silicate (Si).

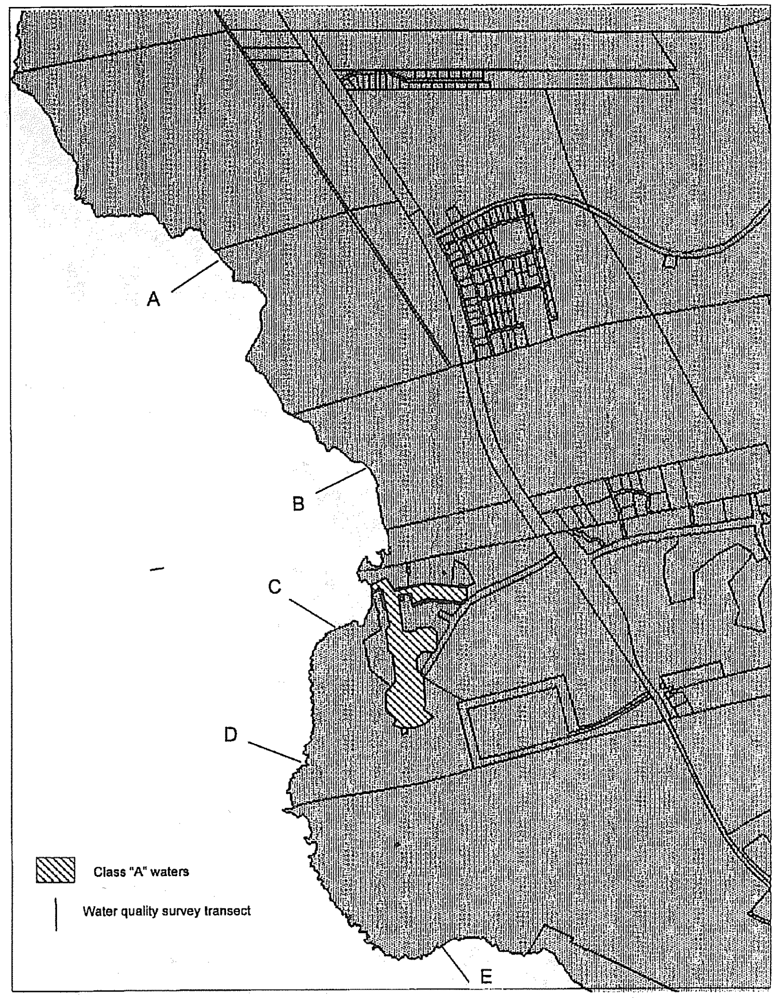

Figure 2. Location of water quality monitoring survey transects at the Kona Kai Ola at Kealakehe project site, Kailua-Kona, Island of Hawaii. Location, size and design of proposed harbor expansion is approximate.

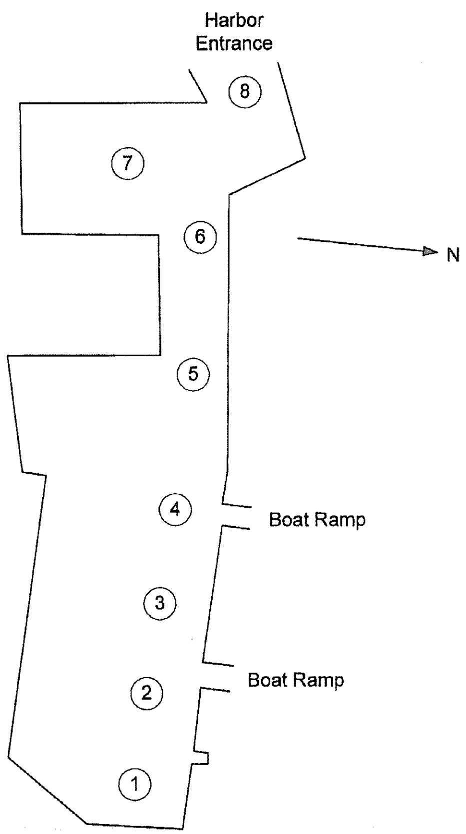

Figure 3. Location of water quality survey stations within Honokohau Harbor, Kailua-Kona, Island of Hawaii.

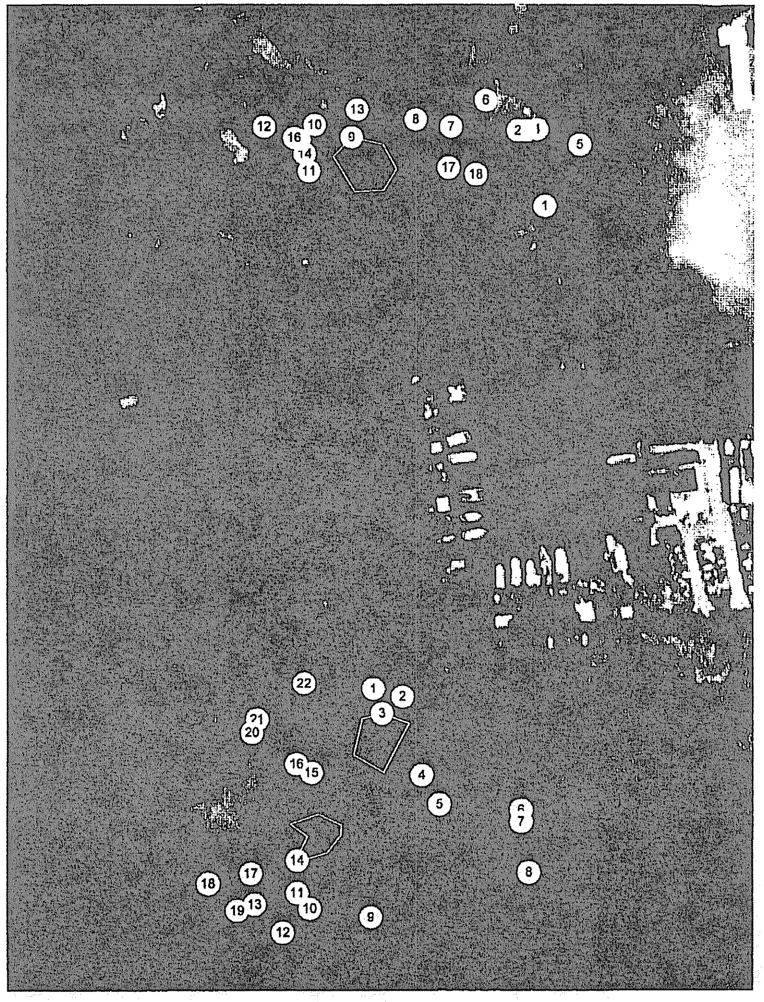

Figure 4. Location of anchialine ponds in areas immediately north and south of Honokohau Harbor entrance channel. Polygons outline extensive interconnected water areas represented by a single sample.

Table 1. Water quality parameters examined during the study, and analytical method.

WATER QUALITY PARAMETER	UNITS	COLLECTION AND ANALYSIS METHOD
Temperature	degrees C.	YSI portable dissolved oxygen/temperature meter
Dissolved Oxygen	mg / liter	YSI portable dissolved oxygen/temperature meter
pH	units	Oakton pH Testr 3+ portable pH meter
Turbidity	National Turbidity Units (NTU)	Hach 2100P turbidimeter; Standard Methods, 1986
Salinity	parts per thousand (ppt)	Laboratory salinometer
Water Samples:		5-liter Niskin bottles
Nutrients		Technicon AutoAnalyzer II;
Total nitrogen	µg N/liter	D'Elia et al., 1977
NH_4	µg N/liter	Solorzano, 1969
NO_3/NO_2	µg N/liter	Technicon Inc., 1977
Total Phosphorus	µg P/liter	Grasshoff et al., 1983
Orthophosphate	µg P/liter	Murphy and Riley, 1962
Silicate	µg Si/liter	Strickland and Parsons, 1972
Chlorophyll	µg /liter	Filtration, acetone extraction, Turner Designs fluorometer; Strickland and Parsons, 1972
Total Suspended Solids	mg/liter	Filtration, electrobalance, Standard Methods, 1986

Geometric means of all parameters were calculated for each survey and for all surveys combined using the Excel spreadsheet GEOMEAN function. Data sets were compared using the means and standard deviations of log-transformed data as input parameters for a 2-sample *t*-test in SYSTAT. Multiple means were tested using three-way analysis of variance (ANOVA) followed by Student-Newman-Kuels pairwise multiple comparison procedures to identify significantly difference means. Parameters describing the regression equations (slope, 95% upper confidence limit of slope) for relationships between parameters were generated using the Excel spreadsheet regression data analysis tool. Probability levels for the calculated *t*-values were determined using the Excel spreadsheet TDIST function. For all statistical tests, significance levels were set at $p = 0.05$.

Results

A conservative element is one whose concentration is not changed by biological process such as excretion, denitrification, uptake, etc. or affected by anthropogenic inputs (fertilization, sewage discharge). If salinity is taken as a conservative element present at approximately 35 ppt in open ocean water and at near 0 ppt in fresh water, then a plot of the concentration of any other conservative element against salinity for a group of randomly-collected samples along a salinity gradient will result in a straight line. A non-conservative element plotted against salinity will show data points above the conservative mixing line if other sources of the element are present, and will show points below the line if active uptake or removal of the element is occurring. Deviations from the mixing line may also occur if there are more than two sources of the element being mixed together. If plots of potentially non-conservative elements (such as nitrate or phosphate) against a conservative element are linear, this implies that no addition or removal by non-conservative processes has occurred.

The concentrations of selected water quality parameters also provide information as to the source of these parameters. For example, silicate is found in extremely high concentrations in fresh or slightly brackish groundwater in all the Hawaiian Islands due to the dissolution of silicate from the basaltic rocks which make up the islands. Nitrate is also found in high concentrations, primarily due to the breakdown of organic material and bacterial action on organics. Ammonium is generally found only in waters fed by wastewater treatment discharges or agricultural fertilization. Phosphate, on the other hand, is generally very low in groundwater because the phosphate molecule is bound up by the typical Hawaiian soils. Open ocean surface sea water is typically high in salinity and low in these dissolved nutrients, with concentrations often below the limit of analytical detection.

Coastal Water Quality

The results of three water quality surveys conducted on April 3, 10 and 14, 2006 along five transects in the Kona Kai Ola area are presented in Appendix A and summarized in Table 2. Results of three-way ANOVA for all water quality parameters are presented in Table 3. The concentrations of salinity, silicate and nitrite plus nitrate-nitrogen (NO3) are shown plotted against distance from the shoreline for the three survey dates in Figures 5A-C. Several general patterns of distribution and concentration for these parameters are evident.

Significant differences in the concentrations of these parameters were seen between surveys, a probable result of differences in conditions during sampling. Surf and wind conditions were generally low during the April 3 survey, increased during the April 10 survey, and were highest during the April 14 survey. Thus, vertical mixing and offshore transport were least strong on April 4 and most pronounced during April 14. Differences in salinity with distance offshore, for example, were clearly seen between transects on April 4, but were not seen between Transects A, C, D and E on April 14. The presence of low-salinity groundwater was most evident on April 3 and April 10, when mean salinity was significantly lower than on April 14. Dissolved oxygen levels were significantly higher on April 14, reflecting the effects of breaking waves and wind mixing on gas exchange. Dissolved nutrient concentrations were either not significantly different between dates, or as for NO3, higher on April 3.

The influence of groundwater influx along the shoreline was most evident at Transect B, located off Kaloko Fishpond (Table 3). Mean salinity levels were uniformly lower than at any other transect, and concentrations of all total and dissolved nutrients were significantly higher. On April 3, a day with light surf and wind conditions, there was strong evidence of groundwater discharge at Transect A, off Aimakapa Fishpond, as well (Figure 5A). Plots of silicate, NO2+NO3 and ortho-phosphate (o-P) versus salinity are presented in Figures 6A-C. These data strongly suggest that the groundwater entering the coastal waters from Wawahiwaa Point to the

Table 2. Geometric means of water quality parameters for three surveys conducted on April 3, April 10 and April 14, 2006. Each value is the geometric mean of the values for that transect and station for the three sampling days. Surface geometric means are the means of valuse for surface samples on each transect. Overall surface geometric mean is calculated on all values for all surface stations and sampling days. Water Quality Geometric Means are the area-specific numerical criterion value for the Kona coast of the island of Hawaii (HAR 11; Chapter 54). Geometric means in bold exceed the respective Chapter 54 area-specific numerical criterion.

	Station DFS (m)	CHLA (ug/L)	Turb (NTU)	DO (mg/L)	Sal (ppt)	Temp deg C	pH	Si (ug/L)	o-P (ug/L)	TDP (ug/L)	NO3-N (ug/L)	TDN (ug/L)	NH4-N (ug/L)	TSS (mg/L)
Transect D	1S	0.29	0.24	7.3	34.0	25.3	8.17	280	3	4	46	134	1	17.5
	10S	0.23	0.18	7.2	34.0	25.3	8.15	208	4	4	47	172	1	31.0
	10B	0.25	0.17	7.4	33.9	25.8	8.14	191	4	4	103	150	1	21.1
	50S	0.13	0.16	7.3	34.0	25.6	8.18	195	3	4	18	157	1	8.3
	50B	0.16	0.15	7.2	34.0	25.6	8.18	151	3	4	14	153	2	18.0
	100S	0.16	0.15	7.2	34.0	25.2	8.15	163	3	4	14	167	2	24.8
	100B	0.16	0.19	7.0	34.0	25.3	8.17	123	2	4	11	144	2	24.8
	500S	0.16	0.21	6.9	33.9	25.2	8.25	139	3	4	21	139	1	16.0
	500B	0.14	0.16	7.1	34.1	25.1	8.19	135	3	4	9	131	1	14.6
Surface Geometric Mean		0.19	**0.18**	7.2	34.0	25.3	8.18	191	3	4	**26**	**153**	1	17.8
Transect E	1S	0.14	0.13	7.2	34.0	25.1	8.18	274	4	6	68	163	1	16.1
	10S	0.13	0.15	7.2	34.1	25.1	8.19	210	3	5	66	166	1	21.8
	10B	0.13	0.27	7.3	34.1	25.1	8.18	164	3	4	67	162	1	28.5
	50S	0.13	0.18	7.2	33.9	25.6	8.17	173	3	5	15	145	1	16.7
	50B	0.14	0.17	7.2	34.1	25.1	8.18	153	3	3	8	109	1	15.4
	100S	0.12	0.17	7.1	34.0	25.0	8.13	197	4	4	15	131	1	13.5
	100B	0.14	0.18	7.2	34.1	25.0	8.19	127	3	4	10	120	1	17.8
	500S	0.14	0.15	7.2	34.2	25.3	8.23	158	3	4	17	130	2	15.8
	500B	0.11	0.16	7.2	34.1	24.9	8.22	224	4	5	11	112	1	14.4
Surface Geometric Mean		0.13	**0.16**	7.2	34.0	25.2	8.18	199	4	5	**28**	**146**	1	16.6
Overall Geometric Mean		0.28	**0.21**	7.4	32.9	25.1	8.15	565	4	6	**63**	**232**	1	18.2
Water Quality Standards		0.30	0.10						5	13	5	100	3	

Table 2. Geometric means of water quality parameters for three surveys conducted on April 3, April 10 and April 14, 2006. Each value is the geometric mean of the values for that transect and station for the three sampling days. Surface geometric means are the means of valuse for surface samples on each transect. Overall surface geometric mean is calculated on all values for all surface stations and sampling days. Water Quality Geometric Means are the area-specific numerical criterion value for the Kona coast of the island of Hawaii (HAR 11; Chapter 54). Geometric means in bold exceed the respective Chapter 54 area-specific numerical criterion.

	Station DFS (m)	CHLA (ug/L)	Turb (NTU)	DO (mg/L)	Sal (ppt)	Temp deg C	pH	Si (ug/L)	o-P (ug/L)	TDP (ug/L)	NO3-N (ug/L)	TDN (ug/L)	NH4-N (ug/L)	TSS (mg/L)
Transect A	1S	1.34	0.38	7.5	32.4	24.7	8.12	2090	4	9	306	423	1	18.5
	10S	0.94	0.21	7.4	32.5	25.0	8.21	1733	4	10	308	532	1	16.7
	10B	1.13	0.23	7.5	32.5	24.7	8.20	1255	4	10	171	343	1	19.5
	50S	0.74	0.21	7.3	32.4	24.9	8.16	1724	3	8	309	477	1	23.5
	50B	0.62	0.20	7.5	32.6	24.5	8.10	1387	3	7	183	321	1	20.3
	100S	0.53	0.16	7.4	32.6	24.7	8.19	1289	4	7	164	323	1	18.2
	100B	0.24	0.17	7.3	33.9	24.9	8.19	514	3	5	45	175	1	16.4
	500S	0.13	0.17	7.2	33.8	25.3	8.18	212	3	6	21	152	1	15.2
	500B	0.14	0.18	7.0	34.0	25.3	8.18	152	3	5	24	131	1	19.3
Surface Geometric Mean		**0.58**	**0.22**	7.4	32.7	24.9	8.17	1113	3	8	**159**	**350**	1	18.2
Transect B	1S	0.81	0.57	7.9	29.7	24.7	8.08	6700	9	16	410	685	2	18.1
	10S	0.81	0.41	8.9	29.8	24.6	8.08	7159	5	16	526	704	2	17.5
	10B	2.05	0.48	8.5	30.7	24.5	8.02	5088	6	14	481	620	1	18.4
	50S	0.68	0.38	8.9	30.2	24.6	8.08	4773	3	11	463	558	2	18.1
	50B	0.71	0.42	8.8	31.3	25.2	8.06	3546	3	8	342	497	1	19.3
	100S	0.50	0.32	8.5	30.6	24.9	8.00	4371	4	7	346	414	2	17.8
	100B	1.05	0.38	9.1	31.8	25.0	8.12	2599	3	5	112	307	1	21.1
	500S	0.41	0.28	7.4	32.8	24.9	8.20	982	3	5	25	159	2	19.2
	500B	0.47	0.28	7.1	33.3	25.1	8.17	605	3	5	20	160	2	21.1
Surface Geometric Mean		**0.62**	**0.38**	8.3	30.6	24.7	8.09	3967	4	10	**243**	**446**	2	18.1
Transect C	1S	0.28	0.19	7.2	33.7	25.2	8.16	332	3	6	127	221	1	27.7
	10S	0.29	0.14	7.1	32.8	25.0	8.11	433	4	7	128	223	1	19.1
	10B	0.23	0.21	7.3	33.8	25.0	8.11	225	3	6	107	175	2	19.1
	50S	0.21	0.18	7.2	33.1	25.1	8.11	342	4	6	26	213	3	29.8
	50B	0.15	0.22	7.2	33.8	25.3	8.15	172	3	5	22	175	1	19.3
	100S	0.21	0.22	6.9	33.0	25.4	8.11	641	5	7	29	199	1	17.4
	100B	0.13	0.17	7.0	34.1	24.9	8.14	157	2	4	15	152	1	15.7
	500S	0.13	0.17	7.0	33.9	24.9	8.18	151	3	4	6	120	1	13.8
	500B	0.15	0.20	7.1	34.2	25.0	8.15	136	2	4	5	122	2	11.9
Surface Geometric Mean		0.21	**0.18**	7.1	33.3	25.1	8.13	343	4	6	**37**	**190**	1	20.7

Table 3. Results of three-way analysis of variance (ANOVA) on water quality parameters from three surveys conducted in the Kona Kai Ola area in April 2006. Significant ANOVA results are indicated by bold type. Values with the same superscript letter are not significantly different (p = 0.05).

	NH4-N (ug/L)	NO3-N (ug/L)	TDN (ug/L)	o-P (ug/L)	TDP (ug/L)	Si (ug/L)
Date						
4/3/2006	1.62 a	161.44 a	299.29 a	3.76 a	5.42 b	1005 b
4/10/2006	0.98 b	127.80 b	248.02 b	3.38 a	6.91 a	1584 a
4/13/2006	1.67 a	89.02 c	217.14 c	3.44 a	6.64 a	1069 b
p=	**<0.001**	**<0.001**	**<0.001**	0.337	**<0.001**	**<0.001**
Transect						
A	0.93 b	183.48 b	330.65 b	3.26 b	7.67 b	1244 b
B	2.29 a	315.33 a	463.70 a	4.44 a	9.85 a	4120 a
C	1.37 b	64.82 c	185.19 c	3.30 b	5.59 c	362 c
D	1.40 b	32.11 c	153.19 c	3.04 b	4.00 d	180 c
E	1.13 b	34.70 c	141.37 c	3.59 b	4.52 d	192 c
p=	**<0.001**	**<0.001**	**<0.001**	**0.003**	**<0.001**	**<0.001**
Station						
1S	1.54 ab	212.67 ab	343.07 ab	4.87 a	8.60 a	2074 a
10S	1.80 ab	229.53 a	372.53 a	4.13 ab	8.60 a	2154 a
10B	1.27 ab	200.20 ab	298.40 bc	4.07 ab	7.60 ab	1474 b
50S	1.98 ab	163.33 bc	305.80 bc	3.13 b	6.77 bc	1424 b
50B	0.96 b	114.00 c	251.43 c	2.93 b	5.57 de	1045 bc
100S	1.26 ab	127.20 c	265.53 c	3.93 ab	6.20 cd	1423 b
100B	1.14 ab	45.60 d	183.13 d	2.73 b	4.27 e	758 cd
500S	1.57 ab	22.53 d	145.27 d	3.07 b	4.67 e	366 d
500B	1.29 ab	19.73 d	137.20 d	2.87 b	4.67 e	259 d
p=	**0.039**	**<0.001**	**0.039**	**<0.001**	**<0.001**	**<0.001**

Table 3. Results of three-way analysis of variance (ANOVA) on water quality parameters from three surveys conducted in the Kona Kai Ola area in April 2006. Significant ANOVA results are indicated in bold type. Values with the same superscript letter are not significantly different (p = 0.05).

	Temp deg C	Sal (ppt)	pH	DO (mg/L)	Turb (NTU)	TSS (mg/L)	CHLA (ug/L)
Date							
4/3/2006	25.40 a	33.08 b	8.16 a	7.36 b	0.24 b	12.59 c	0.319 b
4/10/2006	24.83 b	32.98 b	8.15 a	7.31 b	0.30 c	29.46 a	0.493 a
4/13/2006	24.97 b	33.46 a	8.15 a	7.64 a	0.19 a	21.93 b	0.495 a
p=	**<0.001**	**<0.001**	0.620	**<0.001**	**<0.001**	**<0.001**	**<0.001**
Transect							
A	24.91 bc	33.08 c	8.17 a	7.32 b	0.24 b	20.09 a	0.665 bc
B	24.84 c	31.14 d	8.09 c	8.39 a	0.40 a	20.41 a	0.981 c
C	25.08 b	33.59 b	8.14 b	7.10 b	0.20 b	22.72 a	0.201 b
D	25.39 a	33.98 a	8.18 a	7.19 b	0.19 b	23.18 a	0.191 a
E	25.12 b	34.07 a	8.19 a	7.19 b	0.18 b	20.23 a	0.142 b
p=	**<0.001**	**<0.001**	**<0.001**	**<0.001**	**<0.001**	0.886	**<0.001**
Station							
1S	24.99 a	32.76 d	8.14 bc	7.43 b	0.35 a	22.44 a	0.607 a
10S	24.99 a	32.63 d	8.15 bc	7.57 a	0.22 b	23.97 a	0.506 a
10B	25.05 a	33.00 cd	8.13 bc	7.62 a	0.29 ab	24.23 a	0.913 a
50S	25.15 a	32.81 d	8.14 bc	7.58 a	0.24 b	23.67 a	0.377 a
50B	25.19 a	33.26 c	8.14 bc	7.56 a	0.24 b	19.34 a	0.363 a
100S	25.03 a	32.85 d	8.12 c	7.43 b	0.21 b	21.70 a	0.368 a
100B	25.03 a	33.59 b	8.16 b	7.51 ab	0.21 b	21.36 a	0.370 a
500S	25.11 a	33.72 ab	8.21 a	7.14 bc	0.20 b	17.81 a	0.209 a
500B	25.07 a	33.95 a	8.18 ab	7.11 c	0.21 b	17.41 a	0.211 a
p=	0.793	**<0.001**	**<0.001**	**0.002**	**0.016**	0.868	0.793

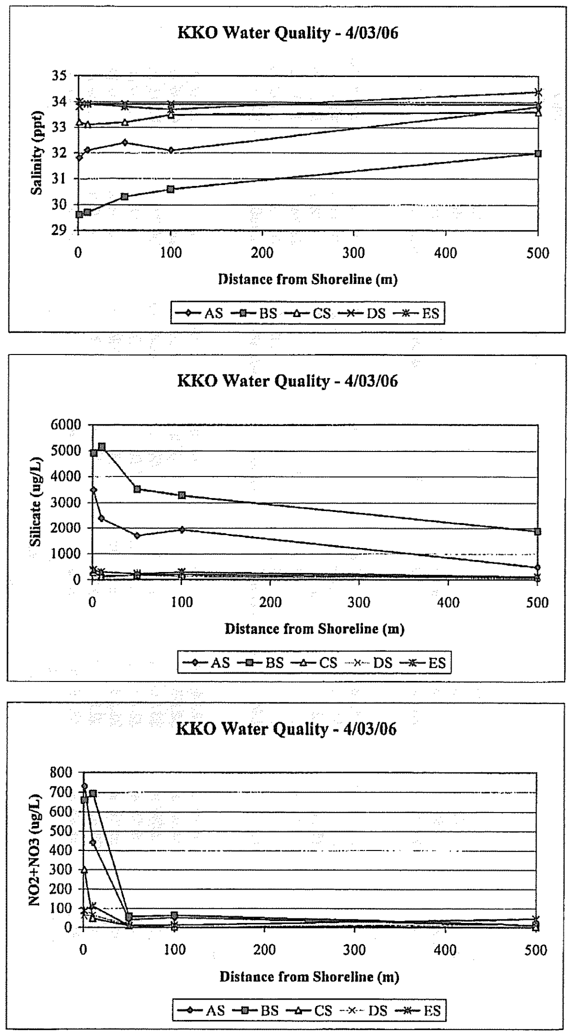

Figure 5A. Plots of salinity, silicate and nitrate+nitrite-N concentrations in surface samples against sample distance from the shoreline for surveys conducted in the Kona Kai Ola study area on April 3, 2006.

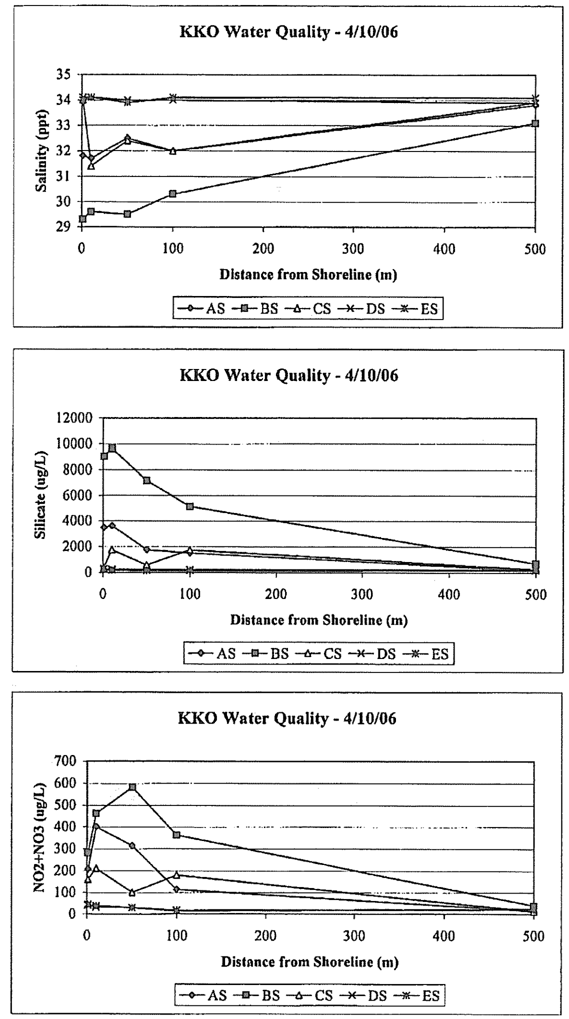

Figure 5B. Plots of salinity, silicate and nitrite+nitrate-N concentrations in surface samples against sample distance from the shoreline for surveys conducted in the Kona Kai Ola study area on April 10, 2006.

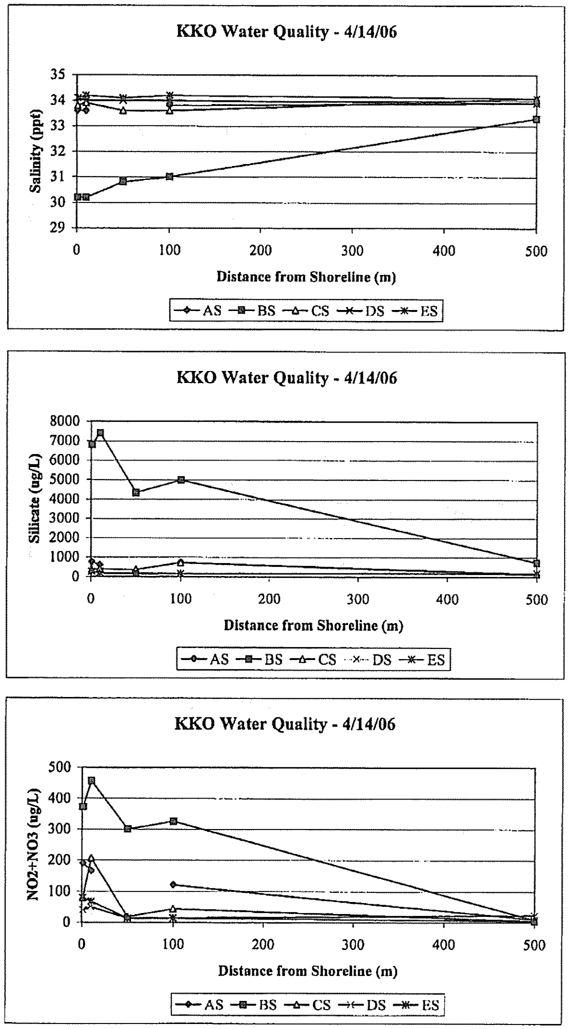

Figure 5C. Plots of salinity, silicate and nitrate+nitrite-N concentration in surface samples against sample distance from the shoreline for surveys conducted in the Kona Kai Ola study area on April 14, 2006.

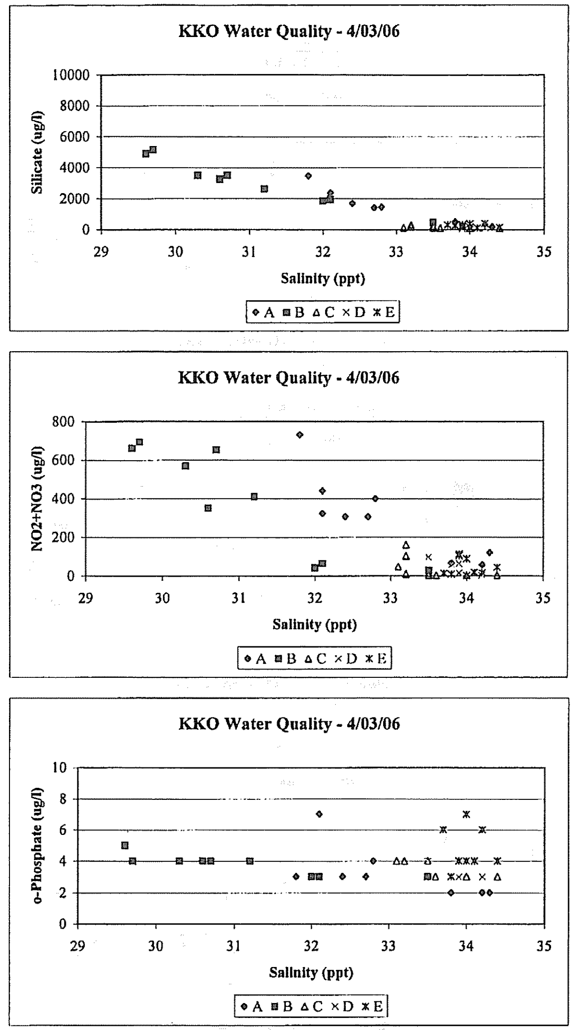

Figure 6A. Plots of concentrations of silicate, nitrite+nitrate-N and o-phosphate against salinity for samples collected at five sites within the Kona Kai Ola study area on April 3, 2006.

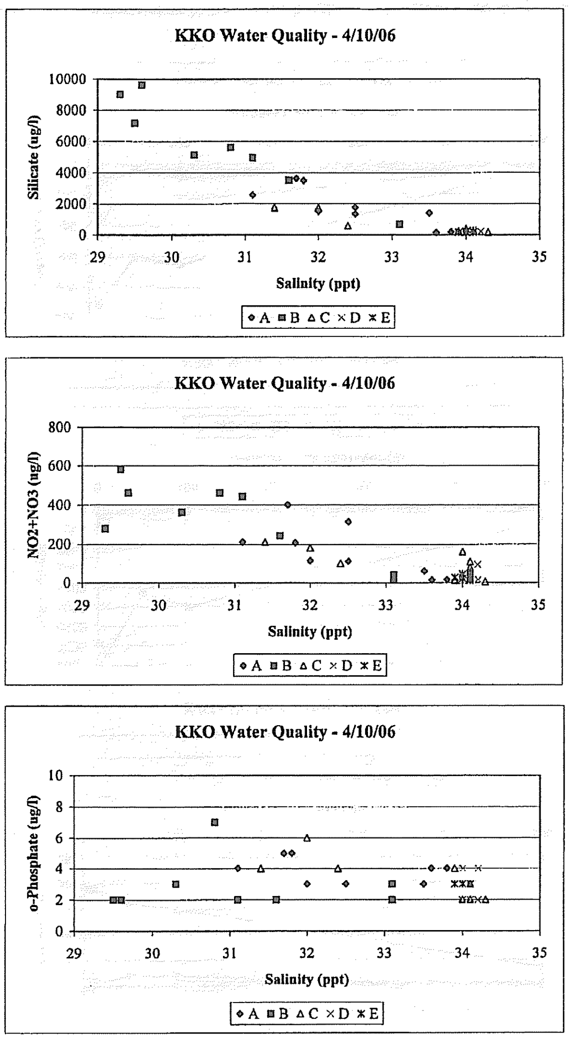

Figure 6B. Plots of concentrations of silicate, nitrite+nitrate-N and o-phosphate against salinity for samples collected at five sites within the Kona Kai Ola study area on April 10, 2006.

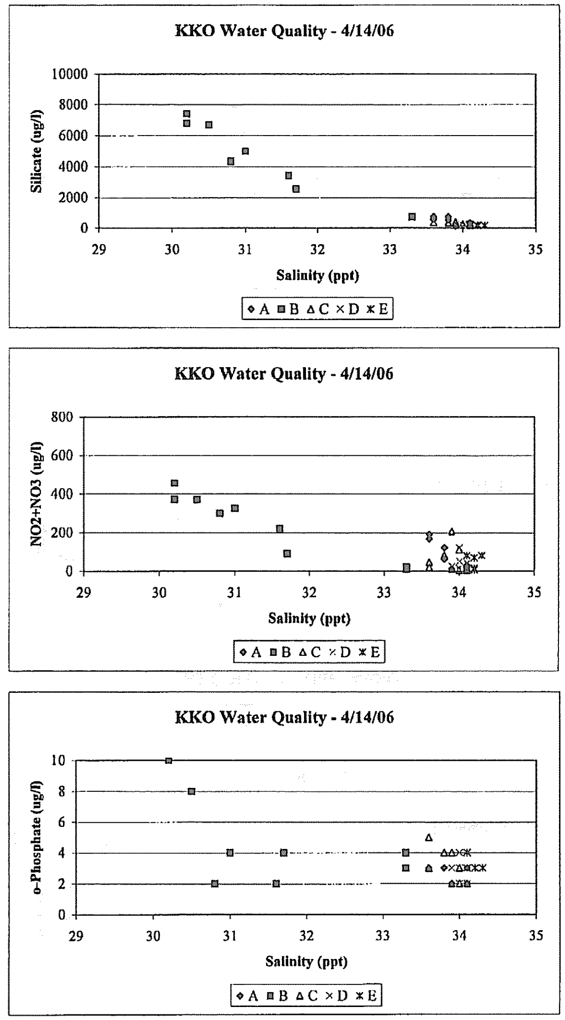

Figure 6C. Plots of concentrations of silicate, nitrite+nitrate-N and o-phosphate against salinity for samples collected at five sites within the Kona Kai Ola study area on April 14, 2006.

north to Keahuolu to the south have the same chemical composition. Plots of silicate versus salinity for all surface samples for all three survey dates show the same linear pattern, with data points from all five transects falling on the same line. Differences in the slope of the line between surveys reflects the differences in mixing conditions during the surveys, or may reflect short-term differences in groundwater influx rates. Plots of NO3 versus salinity show the same linear relationship as silicate, with some differences that may reflect terrestrial vegetative uptake of NO3. For surveys on April 10 and 14, there appears to be no difference between the NO3 – salinity relationships for data from the five survey transects, but there is some evidence in the data from April 3 that NO3 levels along Transect B, off Kaloko Fishpond, may be reduced relative to concentrations at Transect A. Conversely, NO3 levels at Transect A may be elevated relative to Transect B. Since land uses within the Kaloko-Honokohau Park are generally the same and no intensive fertilization is taking place, localized NO3 uptake rather than addition seems the more likely process accounting for the differences observed.

Levels of salinity and all dissolved nutrients were not significantly different with distance from shore between Transects C, D and E. Stations very close to the shoreline (1 and 10 m) at Transect C showed some small depression in salinity and elevation in silicate and NO2+NO3, but not to the degree seen at Transects A and B. For all transects except Transect B, concentrations of these parameters were similar at distances of 500 m from shore. The primary difference between 500 m stations that contributed to the depressed salinity and elevated silicate and NO2+NO3 at Transect B was the broad shallow bottom at that Transect; water depths at 500 m offshore were less than 3 m at Transect B, while they were in excess of 50 m at the other transects. The shallow broad shelf at Transect B reduced mixing of inflowing groundwater with ocean water, and thus maintained the observed high groundwater signature.

Geometric means for each water quality parameter for each station and depth are presented in Table 2. Also presented in Table 2 are the geometric means for surface samples for each transect, the geometric mean for all surface samples for all transects, and the State of Hawaii Chapter 54 water quality standards numerical criterion (geometric mean) for parameters for which numerical criteria have been established. Geometric means for chlorophyll for Transects A and B were similar (0.58 and 0.62 ug/l, respectively) and exceeded the water quality standards numerical criterion; those for Transects C, D and E were well below the criterion level, with levels at Transect E the lowest (0.13 ug/l). Geometric means for turbidity were higher than the numerical criterion for all transects, with highest values at Transect B (0.38 mg/l) and lower an nearly equal values at Transects C, D and E (0.18, 0.18 and 0.16 mg/l, respectively). Geometric means of NO3 and total dissolved nitrogen (TDN) were well above the respective numerical criteria, with highest levels at Transect B, somewhat lower values at Transect A, and much lower and similar values at Transects C, D and E. Levels of ammonium, o-phosphate and total dissolved phosphate were uniformly lower than the respective numerical criteria.

The Chapter 54 water quality standards present a second set of evaluation criteria to be utilized in areas where salinity is less than 32 ppt. Since shoreline and nearshore samples from Transects A and B showed salinities below 32 ppt, the concentrations of o-P, TDP, NO3 and TDN were evaluated using these specific criteria. The criteria for areas where salinity is below 32 ppt require comparison to the upper 95% confidence level of the slope of geometric means of the parameter in question versus salinity. These 95% confidence limits were calculated using the Excel spreadsheet regression function and are presented for the four parameters for each of the five transects in Table 4.

For both o-P and TDP, the slopes of the geometric means of the concentrations versus salinity were not significantly different from zero, thus below the criteria level for those parameters. For NO3, the 95% confidence intervals for the slopes of the regressions with salinity were greater than the standard numerical criteria for Transects A and B. For TDN, the 95% confidence intervals for the slope of the regression with salinity was greater than the standard numerical criteria only for Transects B. Slopes were not significantly different from zero for data from Transects C, D and E.

Honokohau Harbor

Results of water quality surveys conducted within Honokohau Harbor on April 3 (Stations 1 – 4) and April 10 (Stations 5 – 8), 2006 are presented in Table 5. Stations locations are shown in Figure 3. For all stations within the harbor, salinity in the surface samples was significantly lower than in the respective bottom samples. Salinity levels were also lowest in surface samples taken at the mauka end of the harbor (21.5 – 22.6 ppt) increasing to 28.9 ppt at the harbor mouth. Temperature patterns generally mirrored those of salinity, with lower surface temperature and lower temperature at the mauka end of the harbor. Both these parameters reflect the large influx of cool, low salinity groundwater into the harbor. Discharges of groundwater could be seen along the mauka face of the harbor, and at several spots along the southern face as well.

Concentrations of dissolved nutrients reflected their high concentrations in the inflowing groundwater. Plots of silicate, NO3 and o-P versus salinity in surface and bottom harbor samples are presented in Figure 7. Values for silicate fall generally along a single straight line, indicating that harbor waters are receiving a single source of groundwater, and that concentration differences between surface and bottom and from mauka to makai along the harbor are the result of mixing of inflowing groundwater and sea water. Plots of NO3 and o-P versus salinity show some variability in the mixing pattern, and these patterns may be due to the samples for stations 1-4 and 5-8 being collected on different days. For o-P in particular, the patterns of concentration versus salinity of the two survey dates, while being linear, exhibit significant differences in absolute concentration. As shown for coastal water quality parameters, these differences may reflect short-term differences in groundwater quality.

Anchialine Ponds

Results of water quality surveys conducted within anchialine ponds in the Kona Kai Ola area are presented in Table 6. Ponds to the south of the Honokohau Harbor entrance channel were surveyed on April 9, 2006, and ponds to the north were surveyed on April 14, 2006. Pond locations are shown in Figure 4.

The majority of the ponds both north and south of the harbor exhibited salinity levels between 14 – 17 ppt. Ponds nearest the shoreline in both the northern and southern groups exhibited higher salinity, with near-oceanic salinity observed in Pond S20, a pond separated from the ocean by a rubble and sand beach berm.

Table 5. Results of water quality analyses on samples collected within Honokohau Harbor on April 3 and 10, 2006. Station locations are shown in Figure 4. For each station, depth of collection is 0.2 m below the surface (S) or 0.5 m above the bottom (B).

HARBOR Station	Temp °C	Sal ppt	DO mg/L	pH	Turb NTU	TSS mg/L	Chl a ug/L	NH4 ug/L	O2+NO3 ug/L	TDN ug/L	o-P ug/L	TDP ug/L	Si ug/L
1S	24.4	22.6	6.22	8.12	0.34	7.2	0.12	< 1	660	1840	22	86	10810
1B	24.6	29.9	6.52	8.24	0.22	16.0	0.56	< 1	196	589	16	65	6610
2S	24.2	21.5	6.35	8.20	0.21	34.4	0.09	< 1	590	1840	28	84	10320
2B	21.3	30.1	6.48	8.15	0.32	16.4	0.25	< 1	210	788	12	79	5010
3S	24.4	25.3	6.89	8.18	0.21	16.8	0.22	< 1	389	1729	14	90	11220
3B	24.3	30.7	6.57	8.21	0.26	56.0	0.55	< 1	404	660	10	79	5040
4S	25.1	24.9	6.31	8.19	0.16	56.4	0.43	< 1	218	830	16	78	8830
4B	25.7	30.8	6.59	8.18	0.20	60.8	0.54	1.1	206	557	12	66	5320
5S	21.3	25.0	6.22	7.98	0.16	14.9	0.11	< 1	520	1640	16	106	8800
5B	24.3	31.2	6.72	8.07	0.19	18.9	1.16	2.8	190	830	12	90	3704
6S	21.4	26.9	6.24	7.88	0.14	18.4	0.16	1.1	596	2160	22	98	7799
6B	23.9	31.6	6.88	8.03	0.21	17.1	0.90	2.9	240	1200	20	86	6195
7S	23.0	26.4	6.80	7.91	0.16	14.9	0.18	1.9	640	2100	27	88	9768
7B	24.3	32.3	6.83	7.88	0.15	19.7	0.58	2.2	160	1090	10	78	2875
8S	22.9	28.9	6.73	7.79	0.16	16.9	0.20	1.3	430	1617	18	86	6738
8B	24.2	32.4	7.12	7.98	0.15	20.1	0.41	1.9	120	798	8	80	2397

Table 4. Results of linear regression analysis of geometric means of selected water quality parameters on salinity for three sureyvs conducted in April 2006. Values presented are the upper 95% confidence interval for the regression coefficient. "ns" indicates regression coefficients were not significantly different from zero (p = 0.05). Values in bold exceed the Chapter 54 area-specific water quality numerical criteria for the Kona coast of the island of Hawaii.

Transect	o-P	TDP	NO3-N	TDN
A	ns	ns	**-53.80**	-22.00
B	ns	ns	**-69.67**	**-87.14**
C	ns	ns	ns	ns
D	ns	ns	ns	ns
E	ns	ns	ns	ns

Table 6. Results of water quality analyese on samples collected from anchialine ponds located immediately north and south of the Honokohau Harbor entrance channel. Locations of ponds are shown in Figure 4.

Pond	Temperature (°C)	Salinity (ppt)	TAN (ug/L)	NO2+NO3 (ug/L)	TN (ug/L)	o-P (ug/L)	TP (ug/L)	Si (ug/L)
N 1	23.0	16.3	3.06	1632	1785	16	72	25030
N 2	22.0	15.4	2.89	960	1260	14	72	24390
N 3	22.0	15.3	2.27	736	1134	16	70	26390
N 4	22.5	15.2	2.16	400	882	12	79	25640
N 5	22.0	15.3	2.35	768	1239	12	94	26330
N 6	22.5	15.3	1.68	528	1029	14	79	22990
N 7	21.0	16.0	3.06	640	2520	18	80	29860
N 8	21.0	17.2	1.30	800	1911	20	72	24530
N 9	22.0	19.8	2.86	288	1218	8	50	24100
N 10	24.0	24.7	1.86	256	2646	8	65	17040
N 11	24.0	23.2	1.84	368	945	10	58	18510
N 12	24.0	26.0	2.02	800	1260	6	57	12460
S1	25.0	16.4	1.30	2096	2184	18	86	24150
S2	24.3	16.2	1.84	1744	2613	20	98	19550
S4	24.0	14.7	5.08	2048	3315	26	102	20700
S4	24.0	14.7	8.86	2832	3120	32	103	20930
S6	24.0	14.2	1.40	2960	3276	14	108	20700
S9	23.5	12.2	0.43	1936	3003	22	100	27600
S10	24.5	13.3	3.46	2080	3237	17	98	34510
S11	24.0	14.7	4.54	1664	2925	26	97	20240
S13	24.0	14.8	2.27	1808	2730	26	97	24280
S14	25.5	14.7	3.89	1968	3081	22	100	21390
S17	23.0	14.7	2.27	1952	2535	18	99	25450
S18	24.5	14.6	4.86	1984	2240	18	95	26310
S19	25.5	14.8	1.30	1304	1504	22	97	23850
S20	26.3	32.5	1.94	136	735	8	24	3300
S22	29.0	29.4	2.16	266	924	10	31	5260

TAN total ammonia nitrogen
TN total nitrogen
o-P ortho-phosphate
TP total phosphorus
Si reactive silicate

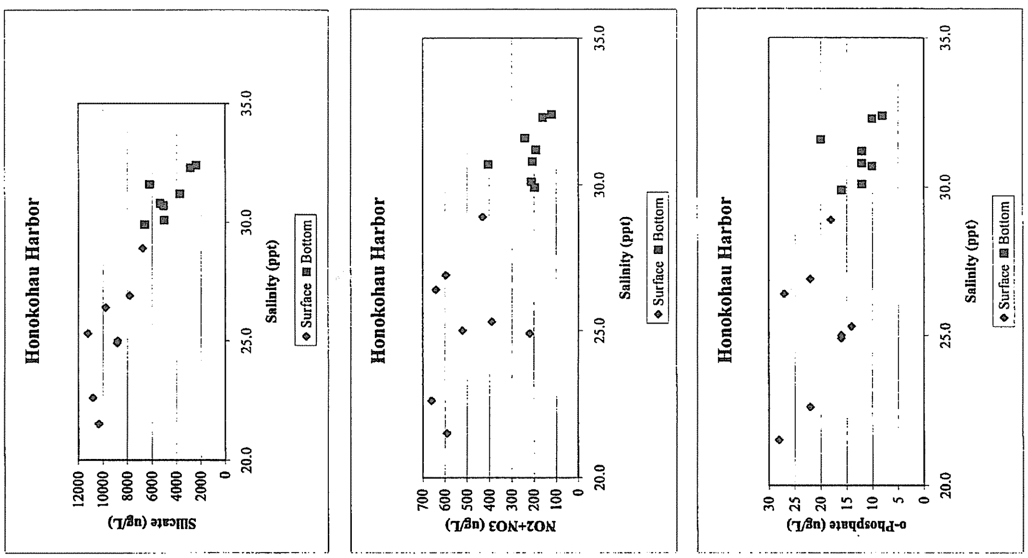

Figure 7. Plots of concentrations of silicate, nitrite+nitrate-nitrogen and o-phosphate against salinity for samples collected within Honokohau Harbor on April 3 and 10, 2006.

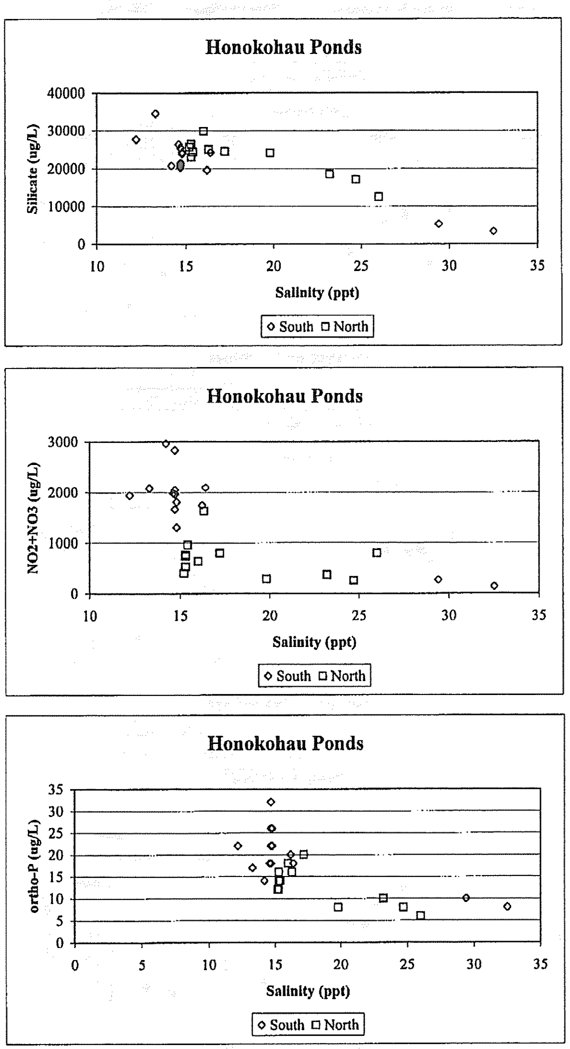

Figure 8. Plots of concentrations of silicate, nitrate+nitrite-nitrogen and o-phosphate versus salinity for samples collected from anchialine ponds locted adjacent the Honokohau Harbor on April 9 and 14, 2006.

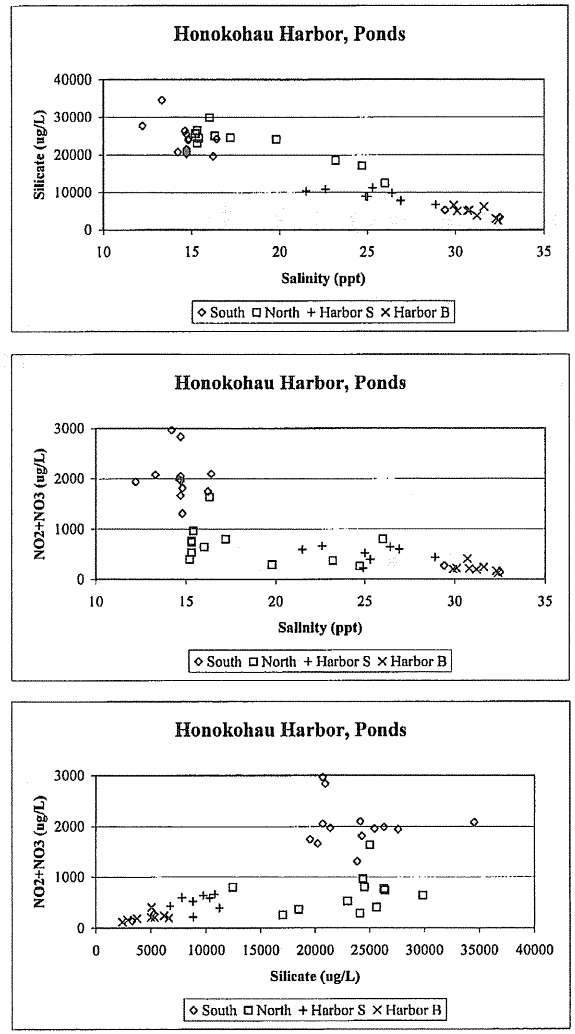

Figure 9. Plots of concentrations of silicate, nitrate+nitrite-nitrogen and o-phosphate versus salinity for samples collected from anchialine ponds and Honokohau Harbor in April 2006.

Dissolved nutrient levels reflected both the mixing of high-nutrient groundwater and low-nutrient ocean water, and biological uptake of dissolved nutrients by aquatic vegetation. The plot of silicate vs salinity (Figure 8A) shows a generally straight line relationship between salinity and dissolved silicate, a conservative (not biologically affected) parameter. The data for both the northern and southern ponds fall generally on the same line, implying that the groundwater entering both pond systems is derived from the same source.

The relationship between NO3-N and salinity was not a simple straight line (Figure 8B), and there appeared to be a difference between the north and south ponds. Levels of NO3 in the north ponds were generally below the conservative mixing line upon which the data for the southern ponds falls. There are several possible causes for the differences in NO3-salinity observed between the northern and southern ponds. Levels in the northern ponds may be reduced relative to the southern ponds due to greater biological uptake in the northern ponds. Ponds in both the northern and southern pond groups were generally heavily vegetated around the edges or within the ponds. Deeper ponds would have relatively exchange rates with the underlying groundwater during tidal cycles, and thus longer residence times. The combination of longer residence times and heavy vegetation may result in biologically-lowered NO3 levels in some of the northern ponds.

The data for dissolved ortho-phophate versus salinity (Figure 8C) appears to show a similar pattern of biological uptake of ortho-phosphate in the northern ponds relative to the southern ponds as well. The plot of total ammonia nitrogen (TAN) versus salinity (not presented) shows no apparent relationship, with similar TAN levels observed over a wide range of salinity, and no apparent differences between northern and southern ponds.

Since both the harbor and the adjacent anchialine ponds receive significant amounts of groundwater, the relationships between salinity, silicate and NO3 were examined. Figure 9 presents plots of silicate and NO3 versus salinity, and of NO3 versus silicate, for all samples collected in Honokohau Harbor and the northern and southern anchialine pond complexes. Figure 9A clearly shows that the silicate versus salinity relationship for all data combined fits a straight, conservative mixing line, suggesting a common source of ground water for the harbor and ponds. Figure 9B shows the plot of NO3 versus salinity for all samples. There is wide variation in NO3 concentrations at low (12 – 17 ppt) salinity, and it is difficult to determine where the conservative mixing line lies, and whether ponds in the southern complex are enriched in NO3 or ponds in the northern complex are depleted in NO3. The plots of silicate versus salinity and NO3 versus salinity exhibit significant variability. This variability may be reduced or minimized by plotting NO3 versus silicate (Figure 9C). These data more clearly show the significant differences in the NO3:Si ratios in the northern and southern pond complexes. Since most ponds in both the northern and southern complexes are vegetated, NO3 uptake is likely to be similar in the two areas. Thus, the data suggest some additional source of NO3 to the ponds in the southern complex, a source which cannot be identified from the available data.

Marine Biological Communities

A single marine biological survey was conducted to establish baseline conditions. The primary biological communities included in the survey were:

1. Biological communities in two clusters of natural anchialine ponds located north and south of the Honokohau Harbor entrance channel;
2. Benthic communities along transects located at each of nine (9) offshore survey sites;
3. Fish communities occurring within the nine (9) offshore survey sites
4. Benthic communities within Honokohau Harbor;
5. Fish communities within Honokohau Harbor.

<u>Anchialine Ponds</u>

Methods

Biota surveys were performed in anchialine ponds located within or immediately adjacent the project site. A total of twenty-two ponds were located and surveyed to the south of the Honokohau Harbor entrance channel on April 9, 2006, and eighteen ponds to the north were surveyed on April 14, 2006 (Figure 4). Temporary quadrats, each 0.33 m x 0.33 m, were placed in each pond where ponds were accessible and sufficient substratum was present to prevent quadrats from overlapping. Counts of motile species were made for each quadrant. Where ponds were too small or inaccessible, estimate of abundance were made. If present, counts of larger motile forms (prawns, crabs or fish) were made.

Results

The results of biota surveys in anchialine ponds to the north and south of the Honokohau Harbor entrance channel are presented in Table 7. Ponds in the northern complex were generally more typical of unimpacted anchialine ponds than those in the southern complex. Almost all ponds in the northern complex had thriving populations of *Halocaridina rubra*, the small red hypogeal caridian shrimp that characterizes the anchialine ponds of the Kona coast. Quadrat counts ranged from 20-25 on the sandy bottoms of several ponds, to densities so high that the bottom appeared red and individual shrimp could hardly be distinguished. The larger shrimp *Metabetaeus lohena*, a predator on *H. rubra*, were observed in small numbers in several northern ponds. No other aquatic animals were observed in the northern complex ponds.

Ponds in the southern complex showed signs of impact and degradation. Many of the southern complex ponds showed remnants of human visitation, including bottles and cans, food wrappers, diapers and toilet paper. While these items generally have little impact on water quality or biological communities, their presence indicates a general disregard for the resource.

Only four of the twenty-two southern ponds examined contained *Halocaridina rubra*; three of those contained *Metabetaeus lohena* as well. Eight of the ponds, however, contained numbers of the introduced topminnow *Poecilia* sp., which is an apparent predator on *H. rubra* and whose presence in a pond generally excludes *H. rubra* and *M. lohena*. In other anchialine pond

Table 7. Results of surveys of anchialine ponds located to the north and south of the Honokohau Harbor entrance channel. Pond locatsion shown in Figure 4. Where data are blank, either no data were collected or no organisms were seen. TNTC = too numerous to count.

Pond	Temperature (°C)	Salinity (ppt)	Bottom type	*Halocaridina rubra*	*Metabetaeus lohena*	*Theodoxus cariosa*	*poecoeliids*
N1	23.0	14	overgrown with Sesuvium		1-3		
N2	22.0	14	open water, sedge in center				
N3	22.0	15	exposed rocks	120-150			
			sand	TNTC			
N4	22.5	15	scattered rock	80			
			intermittent sand	20-25			
N5	22.0	15	flooded grassland; inaccessible				
N6	22.5	15	sedge and Sesuvium	50			
			deeper rocks and sand	25-30			
			shallow rocky shelf	TNTC			
N7	21.0	16	dense Sesuvium, leaf litter				
N8	21.0	17	leaf litter	TNTC			
N9	22.0	19	dense Sesuvium				
			scattered rocks	TNTC			
			sand	TNTC			
N10	24.0	24	organic detritus	150			
			exposed sand, algal mat (Ulva fasciatus)	TNTC			
N11	24.0	22	organic detritus	150			
			exposed sand, algal mat (Ulva fasciatus)	TNTC			
N12	25.0	27	lava and coral rock	50	1-2		
N13	--	--	basalt and coral gravel				
N14	24.0	26	basalt and coral gravel				
N15	--	--	basalt and coral gravel				
N16	--	--	basalt and coral gravel				
N17	--	--	lava crack				
N18	--	--	dense Sesuvium				

Table 7. Results of surveys of anchialine ponds located to the north and south of the Honokohau Harbor entrance channel. Pond locatsion shown in Figure 4. Where data are blank, either no data were collected or no organisms were seen. TNTC = too numerous to count.

Pond	Temperature (°C)	Salinity (ppt)	Bottom type	*Halocaridina rubra*	*Metabetaeus lohena*	*Theodoxus cariosa*	*poecoeliids*
S1	25.0	15	lava rock			6-14	++
S2	24.3	15	lava rock	11-45			
S3			dry				
S4	24.0	11	overgrown with grasses				
S5			water visible but inaccessible				
S6	24.0	11	lava rock	200	2		
S7			damp				
S8			damp				
S9	23.5	9	lava rock	100-120	3		
S10	24.5	11	lava rock				+
S11	24.0	14	dense Sesuvium , some open water			2	++
S12			inaccessible				
S13	24.0	14	lava rock				++
S14	25.5	14	lava rock			4-6	++
S15			dense Sesuvium, scattered open water inaccessible				
S16			damp, dense Sesuvium				
S17	23.0	13	lava crack				
S18	24.5	13	floating algal mat				++
S19	25.5	14	lava rock	6	6		+
S20	26.3	32	coral and lava rubble, mangroves				
S21	26.0	33	coral and lava rubble, mangroves				
S22	29.0	28	sediment bottom, Tilapia nests, mangroves				+

complexes along the Kona coast, the presence of poeciliids generally leads to overgrowth of the ponds by filamentous algae that are usually kept in check by the grazing of *H. rubra*.

Discussion

The planned construction and development activities do not appear to have the potential to significantly impact the ponds in the northern, Koloko-Honokohau National Historical Park complex. All construction and development activities will be separated from the northern ponds by the Honokohau Harbor and entrance channel. No development facilities will be located upstream of the northern ponds, where additions to groundwater might affect pond water quality.

The ponds in the southern complex will be severely negatively impacted by construction of the new harbor, to the extent that any consideration of preservation and/or restoration may be in vain. Construction of the new harbor will significantly alter the pattern of groundwater flow in the area, essentially cutting off the supply of groundwater to the area "downstream" of the harbor (Figure 10). After construction of the new harbor, it is likely these ponds will contain essentially full strength sea water (35ppt). The vegetation and animals living in these ponds are sensitive to salinity. Currently, salinity in the majority of the southern ponds is about 14 ppt, or roughly 40% sea water. None of the brackish water vegetation currently in the ponds can withstand full sea water salinity conditions, so one would expect essentially barren ponds some time soon after the harbor is dredged. Since many of the terrestrial plants also depend on subsurface brackish water, most of the trees in the area will die off as well. While the typical anchialine pond crustaceans (the small red shrimp) are tolerant to a wide range of salinity, they are rarely found in ponds with salinity above 25 ppt.

Our recent survey of the southern ponds showed that many contain exotic fish that essentially exclude the native red shrimp. In general, the southern ponds are more degraded and impacted by natural and human influences than the northern ponds.

Mitigation of the loss of the southern pond resources to construction of the harbor and other facilities might be achieved with replacement man-made ponds somewhere else on the site (a low-lying area near the coastline, behind the beach, a la Waikoloa), or restoring, enhancing or constructing new ponds on another site, such as the adjacent Koloko-Honokohau National Historical Park.

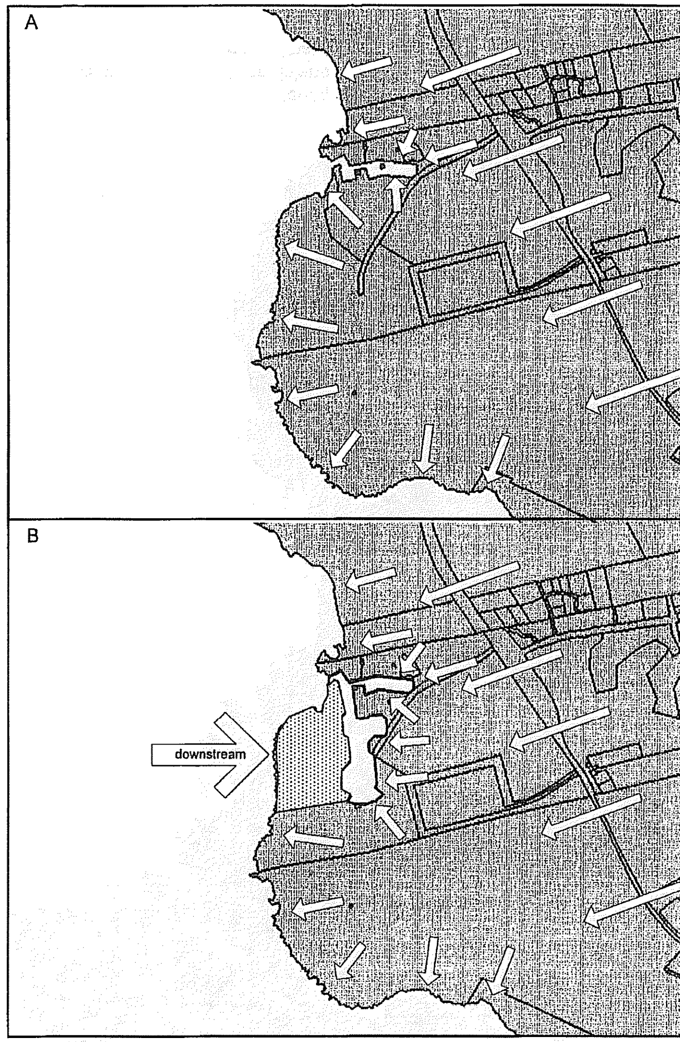

Figure 10. Generalized groundwater flow patterns at Honokohau/Kealakehe (A) under current conditions; (B) after construction of Kona Kai Ola marina.

Coastal Benthic Biota

Methods

Surveys of benthic biota (corals, and associated invertebrates) were conducted at nine survey sites (Figure 11), four to the north of Honokohau Harbor in waters within the Kaloko-Honokohau National Historical Park, four to the south in waters adjacent the project site, and one further south near Keahuolu Point, which served as a control site, with similar conditions but outside the area of potential impact. Surveys were conducted along three 50 meter transect lines at each site. Transect lines were located in water depths of 3 – 5 m, 8 – 12 m, and 15- 20 m, representing locations of distinct bottom habitat types (boulder, reef bench, reef slope, respectively). At each 50 m transect, ten quadrats, each 1.0 m x 0.6 m, were located at random along the transect line. Each quadrat was photographed at close range and at high resolution, e.g., using an underwater camera with a super wide angle lens mounted on a frame for stability, and using underwater strobes to provide uniform lighting. In the laboratory, estimates of the benthic cover of biota and substrata were made using area analysis of the photographs taken in the field in accordance with Bak and Luckhurst, 1980. All invertebrate species greater than 2 mm in size were enumerated and attached forms were assessed in terms of type and percent cover of the bottom. Substrate was also evaluated in terms of percent area coverage.

Species diversity was calculated for coral communities using the Shannon-Weaver Index formula:

$$H = -\sum_{i=1}^{n} (p_i \; ln \, p_i)$$

where p_i = the percent coverage by the i^{th} species in the quadrat.

Data sets were compared using the means and standard deviations of log-transformed data as input parameters for two-way analysis of variance (ANOVA) followed by Student-Newman-Kuels pairwise multiple comparison procedures to identify significantly difference means. For all statistical tests, significance levels were set at $p = 0.05$.

Results

The results of qualitative photoquadrat surveys conducted in the Kona Kai Ola area in April 2006 are presented in Appendix C. Surveys were conducted along 50 m transects located in three depth zones or biotopes (shallow boulders, middle reef shelf and deep reef slope) at nine locations in the Kona Kai Ola area. A detailed summary of percent bottom cover by substrate type and coral species is presented in Table 8. Mean total coral coverage and coverage of the three dominant coral species (*Porites lobata, P. compressa* and *Pocillopora meandrina*) are presented by site and transect biotope in Table 9. Results of two-way analysis of variance for total coral cover, and percent cover of *P. lobata* and *Poc. meandrina* are presented in Table 10.

Figure 11. Location of biological monitoring survey transects at the Kona Kai Ola at Kealakehe project site, Kailua-Kona, Island of Hawaii. Location, size and design of proposed harbor expansion is approximate.

Table 9. Summary of coral community parameters from quantitative surveys conducted between Wawahiwaa (Pinetrees) Point and Kaiwi Point, Island of Hawaii on April 4-13, 2006. Locations of survey sites are shown in Figure 11.

Site		Site A			Site B			Site C	
Transect	Shallow	Mid	Deep	Shallow	Mid	Deep	Shallow	Mid	Deep
Total coral	26.4%	11.4%	4.3%	34.4%	39.5%	25.3%	19.8%	24.4%	3.0%
Porites lobata	15.2%	3.2%	3.6%	34.1%	37.5%	18.3%	19.0%	23.5%	2.6%
Porites compressa	0.0%	0.0%	0.4%	0.0%	0.5%	6.8%	0.4%	0.8%	0.4%
Pocillopora meandrina	10.3%	8.2%	0.2%	0.1%	1.3%	0.0%	0.0%	0.0%	0.0%
Site		Site D			Site E			Site F	
Transect	Shallow	Mid	Deep	Shallow	Mid	Deep	Shallow	Mid	Deep
Total coral	32.0%	47.8%	71.1%	58.2%	82.6%	72.8%	13.8%	32.3%	22.9%
Porites lobata	19.8%	34.2%	31.7%	57.9%	41.6%	53.8%	5.8%	20.7%	10.9%
Porites compressa	0.0%	13.2%	39.1%	0.0%	40.5%	18.6%	0.0%	0.8%	11.6%
Pocillopora meandrina	4.6%	0.4%	0.2%	0.0%	0.2%	0.4%	5.8%	8.8%	0.0%
Site		Site G			Site H			Site I	
Transect	Shallow	Mid	Deep	Shallow	Mid	Deep	Shallow	Mid	Deep
Total coral	19.1%	23.8%	13.0%	26.7%	33.6%	17.3%	27.6%	28.3%	36.2%
Porites lobata	12.6%	19.1%	9.1%	20.2%	25.0%	11.0%	10.0%	20.3%	12.6%
Porites compressa	0.0%	0.1%	3.4%	0.0%	2.2%	6.3%	0.0%	5.7%	22.5%
Pocillopora meandrina	6.0%	4.0%	0.0%	5.2%	6.3%	0.0%	12.2%	1.9%	0.0%

Table 8. Detailed summary of percent coverage for photo-quadrats taken along biota monitoring transects at nine station within the Kona Kai Ola study area in April 2006. Transect locations are shown in Figure 11. Data are results of 200 point analyses of photos of 0.6 x 1.0 m quadrats.

Site	Transect	Sand	Rubble	Rock	*Porites lobata*	dead *P. lobata*	*Porites compressa*	dead *P. compressa*	*Pocillopora meandrina*	dead *P. meandrina*	*Montipora capitata*	*Montipora flabellata*	*Pavona varians*	*Leptastrea purpurea*	*Ralfsia* sp.	Coraline algae	*Asparagopsis taxiformis*	*Anthelia edmondsoni*
A	Shallow	0.0%	1.1%	59.8%	15.2%	0.1%	0.0%	0.0%	10.3%	12.0%	0.2%	0.0%	0.6%	0.1%	0.0%	0.8%	0.0%	0.0%
	Mid	3.5%	0.4%	79.9%	3.2%	0.0%	0.0%	0.0%	8.2%	4.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.8%	0.0%	0.0%
	Deep	3.2%	18.4%	74.1%	3.6%	0.0%	0.4%	0.0%	0.2%	0.0%	0.1%	0.1%	0.0%	0.0%	0.0%	0.2%	0.0%	0.0%
B	Shallow	0.1%	4.4%	54.7%	34.1%	6.0%	0.0%	0.0%	0.1%	0.0%	0.2%	0.0%	0.0%	0.1%	0.0%	0.5%	0.0%	0.0%
	Mid	3.4%	2.2%	34.0%	37.5%	10.1%	0.5%	0.0%	1.3%	0.9%	0.3%	0.0%	0.0%	0.0%	0.1%	0.0%	0.0%	0.0%
	Deep	2.7%	27.4%	26.6%	18.3%	7.0%	6.8%	1.2%	0.0%	0.0%	0.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
C	Shallow	0.0%	0.0%	78.8%	19.0%	0.0%	0.4%	0.0%	0.0%	1.5%	0.2%	0.0%	0.0%	0.2%	0.0%	0.0%	0.0%	0.0%
	Mid	1.0%	2.3%	72.2%	23.5%	0.0%	0.8%	0.3%	0.0%	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	Deep	5.4%	2.3%	89.0%	2.6%	0.0%	0.4%	0.0%	0.0%	0.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
D	Shallow	0.0%	0.0%	64.3%	19.8%	1.4%	0.0%	0.0%	4.6%	1.8%	0.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	7.5%
	Mid	5.8%	14.1%	26.3%	34.2%	4.3%	13.2%	1.5%	0.4%	0.4%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	Deep	2.0%	7.7%	3.5%	31.7%	6.3%	39.1%	4.9%	0.2%	0.0%	0.2%	0.0%	0.0%	0.0%	0.0%	0.0%	4.5%	0.0%
E	Shallow	0.0%	0.0%	41.9%	57.9%	0.0%	0.0%	0.0%	0.0%	0.0%	0.2%	0.0%	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%
	Mid	3.0%	0.4%	6.2%	41.6%	3.1%	40.5%	4.9%	0.2%	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.3%
	Deep	10.9%	0.5%	8.7%	53.8%	2.4%	18.6%	4.9%	0.4%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
F	Shallow	0.2%	0.0%	80.0%	5.8%	0.4%	0.0%	0.0%	5.8%	2.8%	0.3%	1.5%	0.0%	0.6%	0.0%	2.9%	0.0%	0.0%
	Mid	0.8%	3.1%	52.9%	20.7%	8.4%	0.8%	0.5%	8.8%	2.2%	2.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%
	Deep	0.5%	15.0%	41.5%	10.9%	12.7%	11.6%	5.7%	0.0%	0.2%	0.4%	0.0%	0.0%	0.0%	1.6%	0.2%	0.0%	0.0%
G	Shallow	0.4%	0.0%	70.0%	12.6%	1.1%	0.0%	0.0%	6.0%	9.1%	0.3%	0.0%	0.4%	0.0%	0.0%	0.5%	0.0%	0.0%
	Mid	0.1%	0.7%	67.6%	19.1%	4.7%	0.1%	0.0%	4.0%	3.3%	0.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.2%
	Deep	2.4%	3.6%	74.7%	9.1%	0.0%	3.4%	0.8%	0.0%	0.3%	0.5%	0.0%	0.0%	0.0%	0.4%	0.1%	5.0%	0.0%
H	Shallow	4.7%	21.7%	36.3%	20.2%	10.0%	0.0%	0.0%	5.2%	0.7%	0.9%	0.4%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%
	Mid	0.3%	5.7%	38.1%	25.0%	16.0%	2.2%	3.0%	6.3%	1.6%	0.1%	0.0%	0.0%	0.0%	1.6%	0.3%	0.0%	0.0%
	Deep	6.9%	54.8%	4.9%	11.0%	8.9%	6.3%	6.1%	0.0%	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%	0.2%	1.1%	0.0%
I	Shallow	0.0%	1.5%	59.9%	10.0%	0.4%	0.0%	0.0%	12.2%	10.6%	0.5%	0.0%	0.0%	0.1%	0.0%	0.0%	0.0%	4.9%
	Mid	8.5%	19.3%	42.3%	20.3%	0.9%	5.7%	0.5%	1.9%	0.0%	0.4%	0.0%	0.0%	0.0%	0.4%	0.1%	0.0%	0.0%
	Deep	2.6%	4.6%	49.0%	12.6%	0.2%	22.5%	3.1%	0.0%	0.0%	0.1%	0.0%	0.0%	0.0%	1.5%	0.0%	3.0%	1.0%
	Overall Mean	2.7%	8.7%	44.9%	22.0%	4.6%	7.4%	1.9%	3.4%	2.0%	0.4%	0.1%	0.0%	0.1%	0.4%	0.3%	0.6%	0.4%

Table 10. Results of two-way analysis of variance (ANOVA) on coral community parameters from surveys conducted in the Kona Kai Ola study area in April 2006. Significant ANOVA results indicated in bold type. Values with the same superscript letter are not significantly different (p = 0.05).

	Mean Coral Coverage (percent)			
	Total coral cover	*Porites lobata*	*Porites compressa*	*Pocillopora meandrina*
Site				
A	14.0% c	7.3% c	0.1% a	6.2% a
B	33.0% bc	29.9% bc	2.4% a	0.5% a
C	15.7% c	15.0% c	0.5% a	0.0% a
D	50.3% b	28.5% bc	17.4% a	1.7% a
E	71.2% a	51.1% a	19.7% a	0.2% a
F	23.0% c	12.4% c	4.1% a	4.8% a
G	18.6% c	13.6% c	1.2% a	3.3% a
H	25.9% bc	18.7% c	2.8% a	3.8% a
I	30.7% bc	14.3% c	9.4% a	4.7% a
p =	**<0.001**	**<0.001**	0.112	0.116
Station				
Shallow	28.6% a	21.6% a	0.0% b	4.9% a
Mid	35.9% a	25.0% a	7.1% a	3.4% a
Deep	29.5% a	17.0% a	12.1% a	0.1% b
p =	0.310	0.098	**0.042**	**0.007**

Total coral cover was highest (71.2%) at Site E, located immediately south of the Honokohau Harbor entrance channel. Total coral cover at Site D, immediately north of the harbor channel, was next highest (50.3%), but not significantly different form coverage at Sites B, H and I (25.9 – 33.0%). Total coral coverage at Sties A, C, F and G ranged from 14.0 – 23.0%, and was significantly lower than at the other sites.

Overall, *Porites lobata* was the dominant coral species in the Kona Kai Ola area, with average cover of 22.0%. Cover of *P. lobata* was not significantly different between the three biotopes (17.0 – 25.0%). Highest coverage of *P. lobata* (51.1%) was seen at Site E, with somewhat lower coverage at Sties B and D (28.5 – 29.9%). Lower (7.3 – 18.7%) and not significantly different coverage was seen at the remaining sites.

Porites compressa was the next most dominant coral species, with overall average coverage of 7.4%. While the highest coverage (17.4 – 19.7%) of *P. compressa* was observed at Sites D and E, the levels were not significantly different from the other sites (0.1 – 9.4%), because of the significant differences in average cover at the three survey depths. *P. compressa* cover was highest (12.1%) at the deepest transects, but not significantly different from the cover at the reef bench (7.1%). Coverage at both deeper transects were significantly different from the coverage (0.0%) in the shallow boulder zone.

Pocillopora meandrina was the third mot abundant coral species, with average cover of 3.4%. There were no significant differences in *Poc. meandrina* coverage between sies (0.0 – 6.2%). *Poc. meandrina* was most abundant (4.9%) in the shallow boulder zone, but not significantly different from the middle reef bench (3.4%). *Poc. meandrina* was essentially absent from the deep reef slope.

Discusion

Coral communities within the Honokohau Bay and off the Kona Kai Ola site are generally typical of West Hawaii reefs, with little evidence of anthropogenic impacts. Species composition of corals was typical for Kona reefs, with *Porites lobata* and *Pocillopora meandrina* abundant in the shallow and mid-reef zones, and *Porites compressa* present only in the mid-reef and deeper zones. Highest coral abundance was observed at locations immediately to the north and south of the Honokohau Harbor entrance channel. Coral cover at locations north and south of these were not statistically significantly different; however, reefs to the north of Honokohau Harbor in general showed higher coral cover than reefs to the south, primarily because the southern reefs are more exposed to strong surf and associated damage and scour.

Coral communities showed little evidence of negative impact from either general groundwater discharge or from the localized discharge of brackish water from the mouth of Honokohau Harbor. In general, groundwater discharge has no direct impact on coral communities in the Honokohau area because most of the coastline consists of rocky shores with steep shoreline sea cliffs. Water depths at the shoreline are 3 – 5 m, or deeper. Thus, brackish groundwater entering the nearshore zone floats at the surface and rarely comes in contact with deeper corals. The discharge of brackish water from Honokohau Harbor also does not appear to have impacts corals in the immediate vicinity; in fact, coral abundance is greatest at the two transects located immediately north and south of the entrance channel.

Coastal Fish Communities

Methods

Surveys of fish communities were conducted at nine survey sites (Figure 11), four to the north of Honokohau Harbor in waters within the Kaloko-Honokohau National Historical Park, four to the south in waters adjacent the project site, and one further south near Keahuolu Point, which serves as a control site, with similar conditions but outside the area of potential impact. Surveys were conducted along three 25 meter transect lines at each site. Transect lines were located in water depths of 3 – 5 m, 8 – 12 m, and 15- 20 m, representing locations of distinct bottom habitat types (boulder, reef bench, reef slope, respectively). At each site, a visual fish census was conducted to estimate the abundance and biomass of fish present. Data collected included a listing of all species by scientific name, the numbers of individual species and the estimated length of each species for later estimates of standing crop using linear regression techniques. The fish census was conducted over the entire length of the 25 meter transect line. All fish within the 4 X 25 meter transect area to the water's surface were counted.

For fish populations the species diversity was calculated using Shannon's Index of:

$$H' = -\sum_{i=1}^{n} (n_i/n \; ln \; n_i/n)$$

where n_i = the number of individual in the i^{th} species and n = the total number of individuals on the transect.

Data sets were compared using the means and standard deviations of log-transformed data as input parameters for two-way analysis of variance (ANOVA) followed by Student-Newman-Kuels pairwise multiple comparison procedures to identify significantly difference means. For all statistical tests, significance levels were set at $p = 0.05$.

Results

The results of qualitative fish surveys conducted in the Kona Kai Ola area in April 2006 are presented in Appendix D. Surveys were conducted along 25 m transects located in three depth zones or biotopes (shallow boulders, middle reef shelf and deep reef slope) at nine locations in the Kona Kai Ola area. Mean number of individuals, number of species, diversity index and biomass are presented by site and biotope zone in Table 11. Results of two-way analysis of variance for number of individuals, number of species, diversity index and biomass are presented in Table 12.

The fish assemblages in the Kona Kai Ola area were similar to those observed in other areas along the Kona coast, with a small number of species constituting the majority of individuals.

Table 11. Summary of quantitative fish transects conducted between Wawahiwaa (Pinetrees) Point and Kaiwi Point, Island of Hawaii on April 4-13, 2006. Locations of survey sites are shown in Figure 11. Quantitative data are presented in Appendix C.

Station	Site A			Site B			Site C		
Transect	Shallow	Mid	Deep	Shallow	Mid	Deep	Shallow	Mid	Deep
Total number	445	163	476	181	122	332	177	126	215
Number of species	23	23	28	25	18	24	17	22	16
Diversity	1.45	2.49	1.92	2.37	1.79	1.67	1.87	2.29	1.07
Biomass (g/m^2)	275	99	204	82	51	79	231	56	78

Station	Site D			Site E			Site F		
Transect	Shallow	Mid	Deep	Shallow	Mid	Deep	Shallow	Mid	Deep
Total number	78	449	316	121	261	301	252	302	255
Number of species	18	20	20	17	26	23	24	21	26
Diversity	2.39	1.21	1.63	2.31	1.99	1.29	2.58	1.68	2.58
Biomass (g/m^2)	61	73	101	214	64	52	455	100	211

Station	Site G			Site H			Site I		
Transect	Shallow	Mid	Deep	Shallow	Mid	Deep	Shallow	Mid	Deep
Total number	139	251	398	240	268	347	264	296	717
Number of species	19	22	27	25	28	26	20	27	26
Diversity	2.48	1.78	1.73	2.21	2.41	1.47	1.47	2.00	1.38
Biomass (g/m^2)	95	167	166	63	102	46	159	93	126

Table 12. Results of two-way analysis of variance (ANOVA) on fish community parameters from surveys conducted in the Kona Kai Ola study area in April 2006. Significant ANOVA results indicated in bold type. Values with the same superscript letter are not significantly different (p = 0.05).

	Fish Community Parameters			
	Number of individuals	Number of species	Diversity Index	Biomass
Transect				
A	361.3 a	24.7 a	1.953 a	192.7 a
B	211.7 a	22.3 a	1.942 a	70.5 a
C	172.7 a	28.3 a	1.742 a	121.8 a
D	281.0 a	29.3 a	1.741 a	78.4 a
E	227.7 a	22.0 a	1.866 a	109.8 a
F	269.7 a	23.7 a	2.280 a	255.3 a
G	262.7 a	22.7 a	1.995 a	142.9 a
H	285.0 a	26.3 a	2.028 a	70.5 a
I	425.7 a	24.3 a	1.619 a	125.8 a
p =	0.304	0.091	0.808	0.095
Station				
Shallow	210.8 b	20.9 a	2.125 a	181.8 a
Mid	248.7 b	23.0 a	1.961 a	89.4 b
Deep	373.0 a	24.0 a	1.637 a	118.1 ab
p =	**0.023**	0.122	0.102	**0.045**

Two small damselfish (*Chromis agilis* and *C. vanderbilti*) were by far the numerically dominant species. These two, very similar species, generally show very little habitat overlap, with *C. agilis* generally occurring in the reef bench and reef slope zones, and *C. vanderbilti* occurring primarily in the shallow boulder and reef bench zones. A number of other species occurred in relatively large numbers in most of the quantitative survey transects. These included three surgeonfishes: the yellow tang *Zebrasoma flavescens*, the gold-ring surgeonfish *Ctenochaetus strigosus* and the lavender tang *Acanthurus nigrofuscus*. Less common were the saddle wrasse *Thalassoma duperrey*, the arc-eyed hawkfish *Paracirrhites arcatus*, and the chocolate-drop chromis *Chromis hanui*. Several species occurred in large schools at a few locations. These included Thompson's surgeonfish *Acanthurus thompsoni*, the whitebar surgeonfish *Acanthurus leucoparieus*, the Hawaiian sergeant *Abudefduf abdominalis*, the big-scale soldierfish *Myripristis berndti*, the white goatfish *Mulloidichthys flavolineatus* and the yellowfin goatfish *M. vanicolensis*.

No significant differences in the number of individuals, number of species, diversity index or biomass were observed between survey sites (Table 12). Mean numerical abundance of fish was greatest at the deep stations, due primarily to the large numbers of small damselfishes (Chromis agilis and C. vanderbilti). Mean biomass was highest at the shallow stations, due in large part to schools of several species of surgeonfishes.

Harbor Benthic Communities

Methods

Benthic community studies within Honokohau Harbor have focused on the colonization of newly-exposed surfaces by corals and other invertebrates, and examination of long-term patterns of presence and abundance in the harbor as the newly-exposed surfaces weathered and as boat traffic and berthing increased.

The objective of the benthic harbor monitoring survey wass to determine the current patterns of distribution and abundance within Honokohau Harbor using the same stations and survey techniques as for previous surveys, to describe the changes in benthic community structure over time, and to use this information to assess the impacts of construction and presence of the proposed Kona Kai Ola marina.

A single benthic community survey was conducted within Honokohau Harbor on April 11, 2006. Profiles of benthic organism presence, abundance and size were conducted along the vertical walls at 35 sites within the existing harbor, and four sites along the sloped rip-rap wave absorber (Figure 12), the same locations as surveyed in previous studies. Sites within the harbor are numbered from 1 to 41 starting from the southern face of the entrance channel and progressing counter-clockwise. At each site, a contiguous series of 1.0 x 0.6 m photoquadrats was taken from the water surface to the bottom of the vertical wall, using the underwater camera and quadrat frame described above. After being developed and printed, each quadrat photo was examined to identify and determine the size of each individual coral colony. Other macroinvertebrates were identified and enumerated.

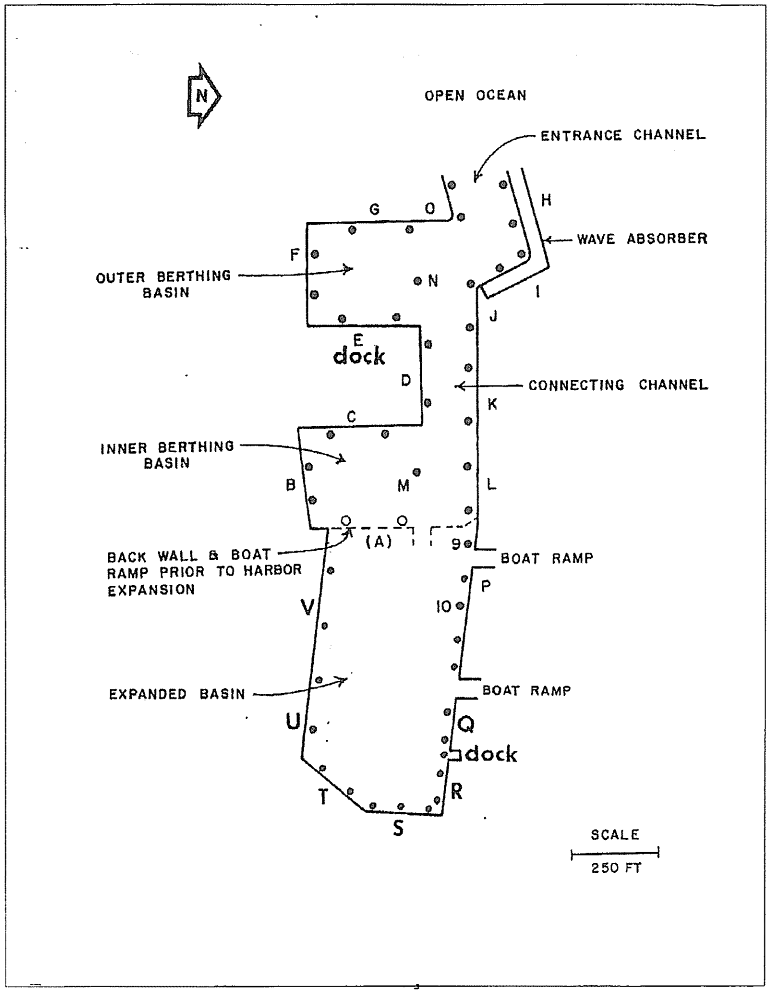

Figure 12. Location of benthic community survey transects within Honokohau Harbor, Kailua-Kona, Island of Hawaii.

Results

Results of surveys of benthic invertebrates on the vertical walls of Honokohau Harbor are presented in Appendix E.

Hard corals occurred commonly only in two areas: the connecting channel between the outer and inner berthing basins (stations 9 – 10 and 34 – 36) and the rip-rap breakwater along the northern side of the harbor entrance channel (stations 37 – 41). Scattered patches of hard corals were found in other parts of the harbor, generally near the bottom and well below the influence of brackish water influx.

Barnacles and purse shells were highly abundant in many locations, primarily within the inner berthing basin and expanded basin. They were most abundant within the upper 1 – 2 m of the sub-tidal harbor walls, apparently favoring the areas washed by brackish water.

Harbor Fish Communities

Methods

Marine fish community studies have focused on the patterns of colonization and long-term residence of fish within Honokohau Harbor from its construction in 1970 to the present. The current study continued that time series of surveys, examining the fish community structure and abundance at six locations within Honokohau Harbor (Figure 13).

At each location, fish presence and abundance was determined by visual census techniques, as described above. A 25 m transect was conducted along the base of the vertical walls at each of the six transect locations. All fish from the surface to the bottom and within 3 m of the vertical walls of the harbor was identified, counted and the size of each estimated for calculation of biomass.

Results

The results of quantitative fish surveys conducted at five locations within Honokohau Harbor on pril 11, 2006 are presented in Table 14. A total of 451 individuals of 31 species were observed within the harbor. The largest number of individuals and species was seen at Station 2, along the vertical concrete wall of the fueling dock. The most commonly-seen species at this station ware the yellow tang *Zebrasoma flavscens* and the Hawaiian sergeant *Abudefduf abdominalis*. Nearly as many individuals and species were seen at Station 3, along the rip-rap breakwater just inside the mouth of the harbor. The lavender tag *Acanthurus nigrofuscus* was ba far the most common species at this station. Station 8, located along the wall of the channel separating the original harbor basin from the expanded basin, had more species but fewer individuals that stations 2 and 3. Most common species here were the spotfin squirrelfish *Neoniphom sammara*, the iridescent squirrelfish *Apogon kallopterus*, the Hawaiian sergeant *Abudefduf abdominalis* and the burrowing goby *Psilogobius mainlandi*. Stations 5, 6 and 7, located at the mauka end of the harbor expansion area, had few species (3-7) and individuals (20 – 38) per transect.

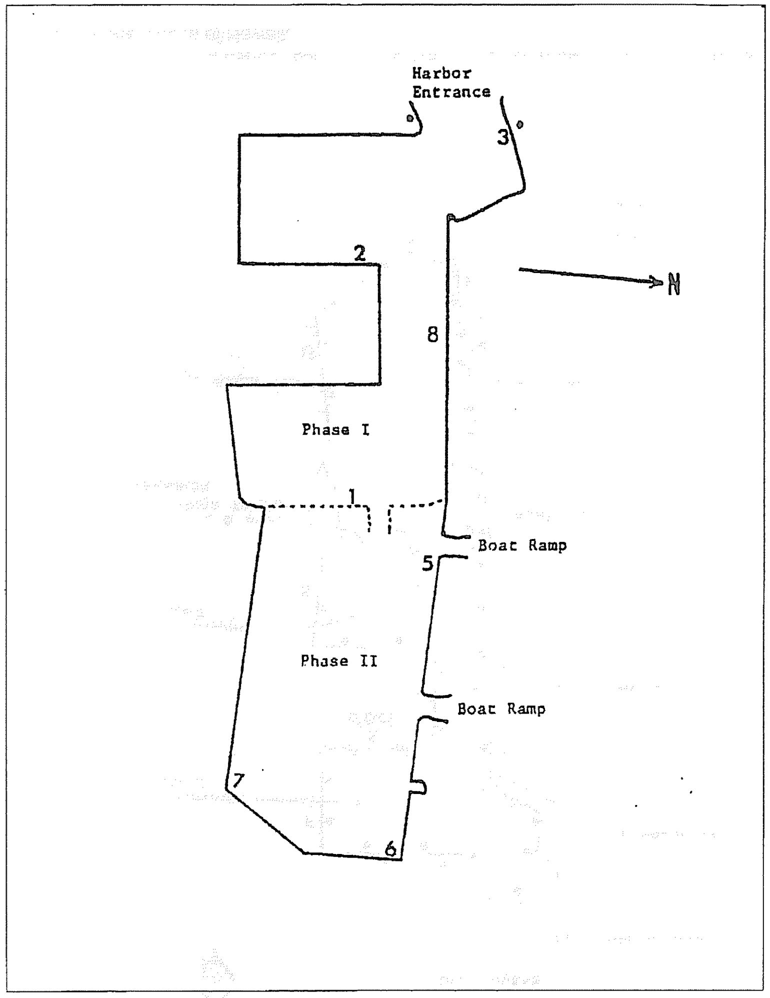

Figure 13. Location of fish survey transects within Honokohau Harbor, Kailua-Kona, Island of Hawaii.

Table 14. Abundance of fish observed along 25 m transects within Honokohau Harbor on April 11, 2006. Station locations are shown in Figure 13. Species listed by taxonomic order.

Family	Species	Station 1	Station 2	Station 3	Station 5	Station 6	Station 7	Station 8	Total
Muraenidae	*Gymnothorax flavimarginatus*							1	1
Synodontidae	*Synodus variegatus*			1					1
Holocentridae	*Neoniphon sammara*	1						17	18
Aulostomidae	*Aulostomus chinensis*		2		1			1	4
Apogonidae	*Apogon kallopterus*							13	13
Mullidae	*Parupeneus multifasciatus*		1						1
	Mulloides vanicolensis		4	3					7
	Mulloides flavolineatus			9					9
Chaetodontidae	*Forcipiger flavissimus*		2					1	3
	Chaetodon lunula		3					1	4
	Chaetodon auriga							2	2
Pomacentridae	*Stegastes fasciolatus*			2				1	3
	Abudefduf sordidus		1					3	4
	Abudefduf abdominalis	3	22			3	16	13	57
Labridae	*Thalassoma duperrey*		3	3					6
	Stenojulis balteata			5					5
	Gomphosus varius		2	3				5	10
Scaridae	*Scarus sp.juvenile*	45	9						54
Gobidae	*Psilogobius mainlandi*	2			20	4		10	36
Zanclidae	*Zanclus cornutus*	3	1	2		6		2	14
Acanthuridae	*Zebrasoma flavescens*		21	2		3	4	1	31
	Ctenochaetus strigosus		15	5				7	27
	Ctenochaetus hawaiiensis		4	1					5
	Acanthurus triostegus	10				2	10		22
	Acanthurus olivaceus			1					1
	Acanthurus nigrofuscus	9	18	48	14			5	94
	Acanthurus leucoparieus	2						1	3
Sphyraenidae	*Sphyraena helleri*				1				1
Ostraciidae	*Ostracion memeagris*	1		5	2				8
Tetraodontidae	*Canthigaster jactator*		3	2		1			6
	Canthigaster coronata					1			1
	Total number	76	111	92	38	20	30	84	
	Number of species	9	16	15	5	7	3	17	
	Diversity	1.4	2.8	2.0	0.9	0.8	0.7	2.5	
	Total biomass	7.1	8.7	7.7	2.7	1.5	2.3	8.9	

SUMMARY

Major development features that have the potential to impact coastal marine resources include changes in land use from undeveloped barren lava to resort/commercial; changes in coastal ocean use due to increased access and marine-related activities; construction of an expanded harbor; construction of an extensive water feature (lagoon); and use of deep cold ocean water to support air conditioning for the development.

Changes in land use will impact the quality of local groundwater entering the coastal waters of Honokohau Bay and the Kona Kai Ola site. Currently, the site is primarily barren or lightly vegetated recent lava. Rainfall is light, and little water is added to the groundwater resource locally. Very little landscape fertilization takes place, so no nutrients are added to the groundwater. Since there are no developed roadways within the site, no petroleum products or metals are generated on site. After development, extensive landscaping will potentially add both water from irrigation and dissolved nutrients, either form localized fertilizer application of from the use of treated wastewater. Pesticide use is likely to be a general part of landscape maintenance, with the potential for leaching to the groundwater as well.

The impacts of these activities on nearshore coastal communities are likely to be small. Groundwater is less dense than ocean water, and the general discharge of groundwater in the area will tend to float on the surface, separated from the corals located at lease 3 – 5 m below.

Construction of an expanded harbor will have several potentially negative impacts on coastal marine resources. Direct construction impacts are likely to be small. Typical harbor construction is done with a berm separating the construction area from adjacent marine waters, minimizing the discharge of sediment from dredging. A pulse of sediment may be discharged when the berm is removed, but the effects of this type of construction activity are generally localized and temporary.

The presence of the expanded marina will significantly alter the pattern of groundwater flow at the Kona Kai Ola site. Essentially the shoreline will move from its current location to the mauka side of the new harbor. Existing groundwater flows will enter the marina rather than reaching the shoreline, so groundwater discharge through the mouth of Honokohau Harbor will increase significantly. Currently, brackish water discharged from the harbor generally flows to the northwest, along the coastline fronting the Kaloko-Honokohau Park. After construction of the new marina, brackish water flows along the Park coastline will increase.

The expanded harbor will serve as a collection point for materials utilized or generated at the development site, either through direct runoff or by interception of groundwater flow. There is the potential that fertilizers, pesticides, petroleum products, road wastes, etc, could be discharged from the mouth of Honokohau Harbor into the coastal marine environment.

The change in groundwater flow patterns due to construction of the expanded marina will have a significant negative impact on anchialine ponds south of the harbor channel. The ponds in the southern complex will be severely negatively impacted by harbor construction to the extent that any consideration of preservation and/or restoration may be in vain. Construction of the new harbor will significantly alter the pattern of groundwater flow in the area, essentially cutting off the supply of groundwater to the area "downstream" of the harbor. After construction of the new harbor, it is likely the southern ponds will contain essentially full strength sea water (35ppt). The vegetation and animals living in these ponds are sensitive to salinity. Currently, salinity in the majority of the southern ponds is about 14 ppt, or roughly 40% sea water. None of the brackish water vegetation currently in the ponds will likely withstand increased salinity conditions, so one would expect essentially barren ponds some time soon after the harbor is dredged. Since many of the terrestrial plants also depend on subsurface brackish water, most of the trees in the area will die off as well. While the typical anchialine pond crustaceans (the small red shrimp) are tolerant to a wide range of salinity, they are rarely found in ponds with salinity above 25 ppt.

The expanded marina will result in an approximately 4-fold increase in boat traffic and related marine activities, including fishing, scuba diving, dolphin and manta ray watching, snorkeling, dinner cruises, etc. Honokohau Bay is currently the most heavily used area along the Kona coast for diving and water-related activities, due to the presence of Honokohau Harbor, the largest and most heavily used recreational and commercial harbor along the Kona coast. Currently, day-mooring buoys installed by the State of Hawaii in the coastal reach from Keahole Point to Keahuolu are near capacity for the dive operators currently operating out of Honokohau Harbor. During times when heavy surf closes out sections of the coastline, boats from Keauhou Bay will add to the demand, often resulting in either an aborted dive trip or boats anchoring rather than utilizing the day mooring. Increased levels of diving activities as the result of the expanded harbor will overload the existing moorings. Mitigation measures could include the installation of additional moorings.

Water for the lagoons and water features will be pumped from offshore depths of approximately 100 ft through a pipe located at the southern project boundary. Water from this depth is typically low in dissolved nutrients, with concentrations often below the limits of analytical detection. Water will be discharged into the mauka portion of the lagoon and flow makai until it discharges into the new harbor basin. This water will then flow out of the harbor with the lower layer of water typically exchanged with each tidal cycle. Since nutrient concentrations in the discharge are expected to be low, no significant biological impacts to nearby coral communities are foreseen.

Air conditioning for the Kona Kai Ola development may be provided by a system utilizing deep, cold ocean water for cooling (SWAC), as an alternative to conventional air conditioning. Under the current concept plan, the SWAC system would draw about 30 million gallons per day of deep ocean water, and 2 – 3 times that volume warm surface water for AC. After passing through heat exchangers to cool working fluids for the air conditioning system, these flows would be discharged down a separate discharge pipe to depths at which the flow temperature matches ambient temperature. If the water increases by 13 degrees F to 53 F, the discharge depths would be about 250 m. This will eliminate the discharge of nutrients into coastal waters and onto sensitive reefs.

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APPENDIX A

Results of water quality analyses of samples collected on April 3, 10 and 14, 2006, along five transects within the Kona Kai Ola study area.

Appendix A. Results of water quality analyses of samples collected on April 3, 2006, along five transects within the Kona Kai Ola study area. Station locations are given in Figure 2

	Station DFS (m)	CHLA (ug/L)	Turb (NTU)	DO (mg/L)	Sal (ppt)	Temp deg C	pH	Si (ug/L)	o-P (ug/L)	TDP (ug/L)	NO3-N (ug/L)	TDN (ug/L)	NH4-N (ug/L)	TSS (mg/L)
Transect D	1S	0.48	0.44	7.3	33.8	25.8	8.26	286	3	5	60	156	1.9	24.8
	10S	0.20	0.28	7.3	33.9	25.4	8.20	171	4	4	64	205	0.5	17.2
	10B	0.25	0.24	7.4	33.5	27.4	8.18	167	4	4	96	132	1.9	19.6
	50S	0.09	0.26	7.3	33.9	26.0	8.29	174	3	4	14	195	3.0	14.0
	50B	0.15	0.18	7.3	33.9	26.1	8.24	117	4	4	13	166	1.8	12.0
	100S	0.15	0.20	7.4	33.9	25.6	8.23	125	4	4	13	244	1.2	12.8
	100B	0.16	0.22	7.1	33.9	25.8	8.26	68	3	3	14	224	3.0	12.0
	500S	0.13	0.21	7.3	33.9	25.6	8.28	68	3	4	17	176	0.5	13.2
	500B	0.16	0.18	7.2	34.2	25.5	8.26	82	3	3	4	184	0.5	10.0
Transect E	1S	0.25	0.12	7.3	34.0	25.8	8.29	372	7	7	88	150	3.6	14.8
	10S	0.21	0.14	7.4	33.9	25.5	8.28	302	4	5	112	178	2.0	11.6
	10B	0.25	0.32	7.3	33.9	25.4	8.27	176	4	5	104	212	2.2	12.7
	50S	0.21	0.46	7.4	33.8	26.0	8.27	232	3	5	9	231	4.0	10.8
	50B	0.23	0.15	7.4	34.0	25.1	8.28	156	4	4	2	95	0.5	12.4
	100S	0.26	0.15	7.4	33.7	25.4	8.13	303	6	6	13	126	0.5	12.4
	100B	0.23	0.23	7.3	34.1	25.1	8.18	97	4	4	19	136	0.5	12.0
	500S	0.23	0.19	7.3	34.4	25.6	8.22	131	4	4	45	230	1.1	12.0
	500B	0.13	0.16	7.4	34.2	25.0	8.26	387	6	7	16	178	0.5	9.6

Appendix A. Results of water quality analyses of samples collected on April 3, 2006, along five transects within the Kona Kai Ola study area. Station locations are given in Figure 2

	Station DFS (m)	CHLA (ug/L)	Turb (NTU)	DO (mg/L)	Sal (ppt)	Temp deg C	pH	Si (ug/L)	o-P (ug/L)	TDP (ug/L)	NO3-N (ug/L)	TDN (ug/L)	NH4-N (ug/L)	TSS (mg/L)
Transect A	1S	1.04	0.19	7.4	31.8	24.7	8.11	3466	3	10	730	860	2.7	11.6
	10S	0.95	0.18	7.4	32.1	25.4	8.22	2371	3	9	440	780	2.9	13.6
	10B	0.77	0.14	7.4	32.8	25.1	8.24	1454	4	10	400	578	0.5	15.2
	50S	0.67	0.16	7.3	32.4	25.5	8.18	1691	3	8	306	566	0.5	15.2
	50B	0.54	0.22	7.3	32.7	24.6	8.03	1418	3	7	305	496	0.5	16.6
	100S	0.67	0.13	7.3	32.1	25.1	8.22	1927	7	7	322	496	0.5	8.7
	100B	0.24	0.15	7.2	34.2	25.2	8.17	288	2	4	57	160	0.5	9.6
	500S	0.18	0.17	7.1	33.8	25.5	8.16	484	2	4	66	178	0.5	4.4
	500B	0.15	0.16	7.1	34.3	25.4	8.18	165	2	3	120	126	0.5	14.8
Transect B	1S	0.47	0.54	7.3	29.6	24.2	7.95	4908	5	11	660	820	3.0	11.2
	10S	0.38	0.37	7.5	29.7	24.9	7.93	5156	4	11	692	796	4.6	11.2
	10B	0.71	0.52	7.2	30.7	24.6	7.90	3519	4	10	652	752	0.5	10.4
	50S	0.44	0.39	8.0	30.3	24.7	7.93	3506	4	10	570	680	5.9	12.0
	50B	0.48	0.45	9.0	31.2	26.6	8.02	2633	4	6	410	570	0.5	10.0
	100S	0.31	0.31	7.8	30.6	25.8	7.87	3271	4	6	350	410	2.6	9.6
	100B	0.55	0.36	8.7	32.1	25.5	8.06	1950	3	4	64	302	2.3	14.4
	500S	0.19	0.27	7.9	32.0	25.6	8.17	1869	3	4	41	188	2.6	11.6
	500B	0.28	0.20	7.4	33.5	25.5	8.05	458	3	3	29	178	3.0	11.6
Transect C	1S	0.20	0.12	7.2	33.2	25.5	8.17	282	4	4	160	302	0.5	14.4
	10S	0.19	0.12	7.1	33.1	25.2	8.06	114	4	5	48	135	0.5	12.4
	10B	0.19	0.15	7.2	33.2	25.1	8.15	157	4	4	103	144	1.3	16.0
	50S	0.18	0.15	7.1	33.2	25.1	8.15	190	4	4	10	171	3.2	12.0
	50B	0.14	0.33	7.1	33.5	25.4	8.17	108	4	4	13	122	0.5	14.4
	100S	0.17	0.16	6.9	33.5	25.5	8.12	208	4	4	3	98	0.5	10.8
	100B	0.18	0.14	6.9	34.0	25.1	8.12	77	3	3	4	120	0.5	11.2
	500S	0.13	0.19	6.9	33.6	25.2	8.22	90	3	4	3	106	0.5	8.4
	500B	0.20	0.34	7.1	34.4	25.1	8.19	89	3	3	4	116	1.9	11.2

Appendix A. Results of water quality analyses of samples collected on April 10, 2006, along five transects within the Kona Kai Ola study area. Station locations are given in Figure 2

	Station DFS (m)	CHLA (ug/L)	Turb (NTU)	DO (mg/L)	Sal (ppt)	Temp deg C	pH	Si (ug/L)	o-P (ug/L)	TDP (ug/L)	NO3-N (ug/L)	TDN (ug/L)	NH4-N (ug/L)	TSS (mg/L)
Transect D	1S	0.2	0.23	7.19	34.1	25	8.15	286	2	4	40	116	0.5	9.2
	10S	0.26	0.19	6.97	34.1	25.2	8.14	237	3	4	32	147	1.4	74
	10B	0.3	0.17	7.21	34.2	25	8.14	200	4	4	94	138	1.9	19.6
	50S	0.18	0.15	7.11	34	25.4	8.19	224	4	4	30	128	0.5	1.6
	50B	0.17	0.16	7.02	34.2	25.5	8.24	168	2	4	16	146	1.1	18.8
	100S	0.2	0.14	6.82	34	25	8.13	207	2	4	15	130	1.3	72
	100B	0.18	0.2	6.79	34	25	8.15	170	2	4	7	96	1.2	63.6
	500S	0.18	0.21	6.78	33.9	25	8.24	198	3	4	24	112	0.5	15.6
	500B	0.18	0.18	6.54	34	24.8	8.25	173	3	4	13	88	1.4	13.6
Transect E	1S	0.13	0.17	7.16	34	24.8	8.15	216	3	7	44	179	0.5	15.6
	10S	0.11	0.21	7.24	34.1	24.8	8.18	166	3	5	38	178	0.5	46.4
	10B	0.1	0.36	7.25	34.1	~~24.8~~	~~8.17~~	147	3	4	36	144	0.5	87.6
	50S	0.11	0.14	7.14	33.9	26		147	3	5	28	105	0.5	18.8
	50B	0.12	0.27	6.96	34	25.1	8.16	141	3	3	22	105	0.5	15.2
	100S	0.09	0.15	6.91	34.1	24.7	8.16	154	3	4	18	136	1.1	6.8
	100B	0.11	0.17	7	34.1	24.8	8.27	143	3	4	10	105	1.2	22.8
	500S	0.1	0.2	7.11	34.1	25	8.28	172	3	4	22	84	1.6	14
	500B	0.11	0.16	6.97	34.1	24.8	8.28	147	3	5	28	80	0.5	13.6

Appendix A. Results of water quality analyses of samples collected on April 10, 2006, along five transects within the Kona Kai Ola study area. Station locations are given in Figure 2

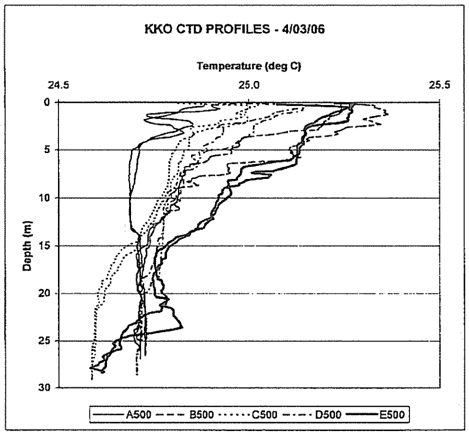
	Station DFS (m)	CHLA (ug/L)	Turb (NTU)	DO (mg/L)	Sal (ppt)	Temp deg C	pH	Si (ug/L)	o-P (ug/L)	TDP (ug/L)	NO3-N (ug/L)	TDN (ug/L)	NH4-N (ug/L)	TSS (mg/L)
Transect A	1S	1.14	1.36	7.67	31.8	24.4	8.12	3484	5	9	206	325	0.5	22
	10S	1.11	0.28	7.62	31.7	24.6	8.24	3609	5	11	400	640	0.5	18.4
	10B	1.9	0.51	7.69	31.1	24.2	8.2	2571	4	10	210	325	0.5	18.8
	50S	0.82	0.28	7.3	32.5	24.3	8.15	1758	3	8	313	402	0.5	36.4
	50B	0.72	0.19	7.67	32.5	24.4	8.18	1356	3	8	110	208	1.1	24.8
	100S	0.78	0.19	7.72	32	24.3	8.21	1513	3	8	114	226	0.5	28
	100B	0.35	0.21	7.32	33.5	24.6	8.21	1405	3	6	60	156	1.1	26.4
	500S	0.14	0.2	6.92	33.8	25.1	8.19	169	4	8	15	186	0.5	36.8
	500B	0.16	0.19	6.82	33.6	25.7	8.18	142	4	7	14	210	0.5	24
Transect B	1S	0.91	0.53	8.62	29.3	24.5	8	9029	14	16	280	815	0.5	25.6
	10S	1.08	0.54	8.91	29.6	24.1	8.06	9617	2	19	461	772	0.5	29.6
	10B	2.38	0.56	8.1	30.8	24.1	7.92	5600	7	16	460	566	0.5	29.6
	50S	0.72	0.49	8.88	29.5	24.3	8	7164	2	12	582	657	1.1	24
	50B	0.75	0.64	8.35	31.1	24.2	7.87	4943	2	9	442	566	1.1	29.2
	100S	1.67	0.37	7.79	30.3	24.4	7.85	5128	3	7	362	436	1.2	25.6
	100B	1.49	0.53	8.79	31.6	24.5	8.06	3517	2	4	242	368	1.3	34
	500S	0.66	0.38	7.05	33.1	24.5	8.11	686	3	5	40	178	1.1	27.6
	500B	0.7	0.54	6.7	33.1	24.9	8.12	679	2	5	14	196	0.5	32.8
Transect C	1S	0.36	0.31	7.12	34	24.9	8.21	376	2	10	160	199	1.6	82.4
	10S	0.37	0.16	6.8	31.4	24.8	8.16	1747	4	8	210	315	1.7	25.6
	10B	0.24	0.26	7.28	34.1	25	8.19	289	3	8	108	198	1.7	16.8
	50S	0.18	0.29	7.24	32.4	25	8.12	576	4	7	100	206	3.6	96.4
	50B	0.16	0.19	7.14	34.1	25.5	8.18	263	2	7	78	184	0.5	26
	100S	0.18	0.26	6.79	32	25.8	8.16	1751	6	14	180	260	0.5	18.4
	100B	0.12	0.21	6.85	34.1	24.8	8.2	246	2	4	56	164	0.5	16.8
	500S	0.13	0.17	6.82	33.9	24.8	8.24	244	4	4	12	96	2.4	14
	500B	0.13	0.19	6.92	34.3	24.8	8.16	163	2	4	5	90	1.6	6.8

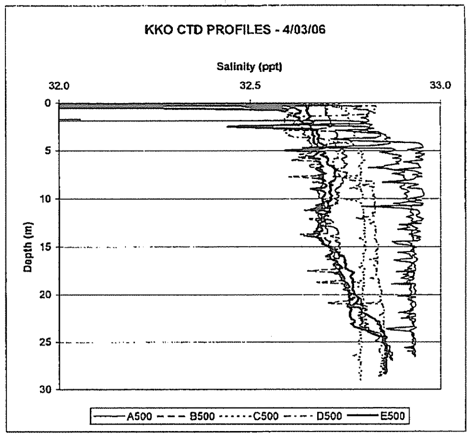
Appendix A. Results of water quality analyses of samples collected on April 3, 2006, along five transects within the Kona Kai Ola study area. Station locations are given in Figure 2

	Station DFS (m)	CHLA (ug/L)	Turb (NTU)	DO (mg/L)	Sal (ppt)	Temp deg C	pH	Si (ug/L)	o-P (ug/L)	TDP (ug/L)	NO3-N (ug/L)	TDN (ug/L)	NH4-N (ug/L)	TSS (mg/L)
Transect D	1S	0.26	0.13	7.42	34.1	25.2	8.11	267	4	4	40	134	1.4	23.5
	10S	0.23	0.12	7.44	34	25.3	8.11	222	4	5	50	168	2.2	23.4
	10B	0.2	0.13	7.62	34	25.2	8.11	209	3	4	120	184	0.5	24.3
	50S	0.15	0.1	7.44	34	25.3	8.07	191	3	4	13	155	0.5	25.8
	50B	0.16	0.12	7.34	34	25.3	8.07	174	3	4	13	148	2	25.8
	100S	0.13	0.12	7.3	34	24.9	8.09	168	2	4	14	148	2.4	16.6
	100B	0.13	0.16	7.22	34.1	25.2	8.09	160	2	4	14	140	1.4	20
	500S	0.18	0.21	6.78	33.9	25	8.24	198	3	4	24	136	2.8	20
	500B	0.1	0.12	7.51	34	24.9	8.06	173	2	4	13	140	0.5	22.9
Transect E	1S	0.08	0.12	7.04	34.1	24.7	8.11	255	4	5	80	160	0.5	18.1
	10S	0.09	0.11	7.03	34.2	24.9	8.10	185	3	5	68	144	0.5	19.2
	10B	0.09	0.17	7.17	34.3	25	8.10	172	3	4	80	140	0.5	20.8
	50S	0.09	0.09	7.15	34.1	24.9	8.08	153	3	4	14	126	1	22.9
	50B	0.1	0.12	7.16	34.2	25.1	8.09	162	3	3	13	130	1.2	19.4
	100S	0.08	0.2	6.92	34.2	24.9	8.11	163	3	3	14	132	1.5	29.3
	100B	0.1	0.14	7.13	34.2	25.1	8.12	149	3	4	6	120	0.5	20.6
	500S	0.13	0.1	7.22	34.1	25.2	8.18	176	3	3	5	115	2	23.7
	500B	0.09	0.17	7.4	34.1	24.8	8.12	197	3	3	3	98	1	23

Appendix A. Results of water quality analyses of samples collected on ~~April 3~~ 14, 2006, along five transects within the Kona Kai Ola study area. Station locations are given in Figure 2

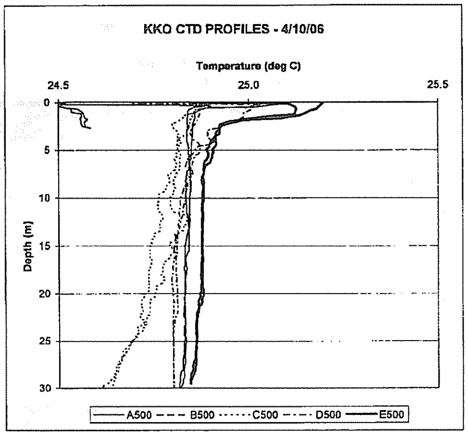
	Station DFS (m)	CHLA (ug/L)	Turb (NTU)	DO (mg/L)	Sal (ppt)	Temp deg C	pH	Si (ug/L)	o-P (ug/L)	TDP (ug/L)	NO3-N (ug/L)	TDN (ug/L)	NH4-N (ug/L)	TSS (mg/L)
Transect A	1S	2.05	0.21	7.45	33.6	25	8.14	756	3	9	190	270	1.7	24.9
	10S	0.8	0.18	7.21	33.6	25	8.17	608	3	11	166	302	2	18.6
	10B	0.99	0.17	7.3	33.8	24.9	8.15	529	3	9	60	215	0.5	26.1
	50S													
	50B													
	100S	0.28	0.16	7.21	33.8	24.7	8.14	735	3	6	120	300	0.5	24.8
	100B	0.17	0.15	7.29	34.1	24.9	8.18	335	3	6	26	216	1.2	17.4
	500S	0.09	0.15	7.48	33.9	25.2	8.18	117	2	6	10	106	1.8	21.6
	500B	0.12	0.18	7.2	34.1	24.9		149	2	7	8	84	0.5	20.3
Transect B	1S	1.23	0.65	7.99	30.2	25.3	8.28	6786	10	22	372	480	2.9	20.6
	10S	1.28	0.34	10.49	30.2	24.7	8.24	7399	12	20	456	568	6.7	16.2
	10B	5.07	0.38	10.59	30.5	24.9	8.24	6683	8	16	370	560	3.3	20.2
	50S	1	0.28	9.93	30.8	24.8	8.33	4328	2	12	300	388	2.3	20.5
	50B	0.99	0.26	9.18	31.6	25	8.30	3426	2	8	220	380	1.8	24.5
	100S	0.24	0.3	10.18	31	24.6	8.30	4979	4	10	326	396	3.4	23
	100B	1.43	0.28	9.76	31.7	25	8.25	2559	4	6	90	260	0.5	19.1
	500S	0.54	0.21	7.17	33.3	24.6	8.32	738	4	7	9	120	3.7	22.1
	500B	0.53	0.21	7.27	33.3	25	8.33	712	3	7	20	118	4.4	24.8
Transect C	1S	0.3	0.18	7.31	33.8	25.1	8.10	344	4	6	80	180	1.3	17.9
	10S	0.33	0.14	7.31	33.9	25	8.10	407	4	7	206	260	0.5	22.1
	10B	0.25	0.22	7.52	34	25	8.00	251	3	6	110	188	2.8	25.8
	50S	0.27	0.13	7.2	33.6	25.1	8.07	366	3	6	18	276	1.8	22.9
	50B	0.16	0.16	7.24	33.9	25	8.10	179	2	5	10	240	0.5	19.2
	100S	0.31	0.26	7.04	33.6	24.8	8.05	722	5	6	44	310	1.2	26.7
	100B	0.11	0.17	7.25	34.1	24.9	8.10	206	2	4	15	180	1.4	20.5
	500S	0.12	0.16	7.32	34.1	24.7	8.08	158	2	5	5	168	2	22.2
	500B	0.12	0.13	7.3	34	25	8.10	172	2	5	5	172	2	22.1

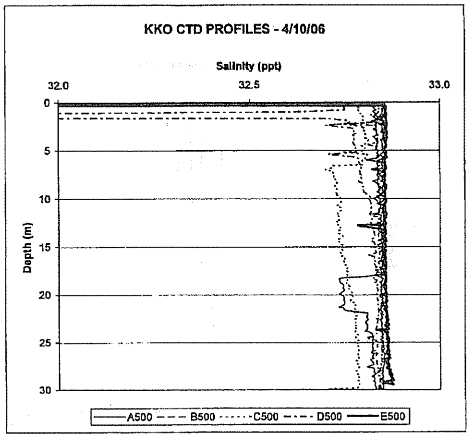




APPENDIX B

Vertical profiles of temperature and salinity collected on April 3, 10 and 14, 2006, at selected stations along five transects within the Kona Kai Ola study area.


KKO CTD PROFILES - 4/10/06
Temperature (deg C)
24.5
25.0
25.5
Depth (m)
0
5
10
15
20
25
30
A500
B500
C500
D500
E500


KKO CTD PROFILES - 4/10/06
Salinity (ppt)
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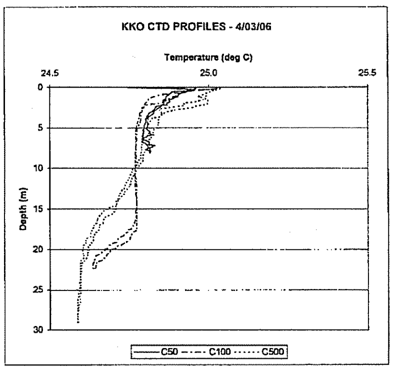
32.5
33.0
Depth (m)
0
5
10
15
20
25
30
A500
B500
C500
D500
E500


KKO CTD PROFILES - 4/03/06
Temperature (deg C)
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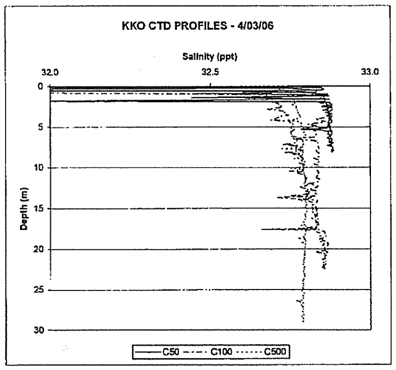
25.0
25.5
Depth (m)
0
5
10
15
20
25
30
C50
C100
C500


KKO CTD PROFILES - 4/03/06
Salinity (ppt)
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32.5
33.0
Depth (m)
0
5
10
15
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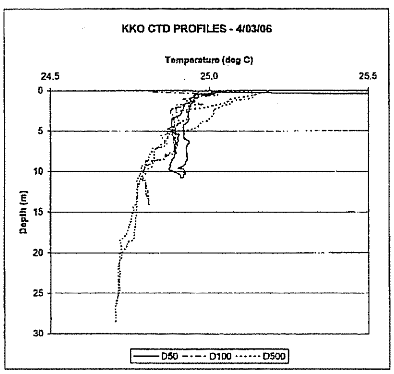
30
C50
C100
C500


KKO CTD PROFILES - 4/03/06
Temperature (deg C)
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25.0
25.5
Depth (m)
0
5
10
15
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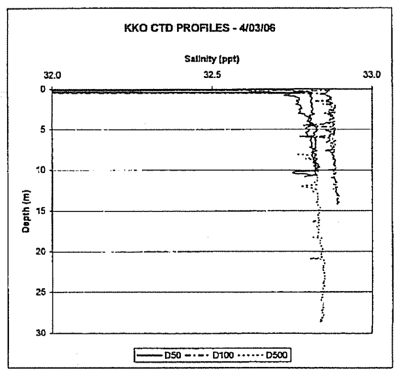
25
30
D50
D100
D500


KKO CTD PROFILES - 4/03/06
Salinity (ppt)
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32.5
33.0
Depth (m)
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5
10
15
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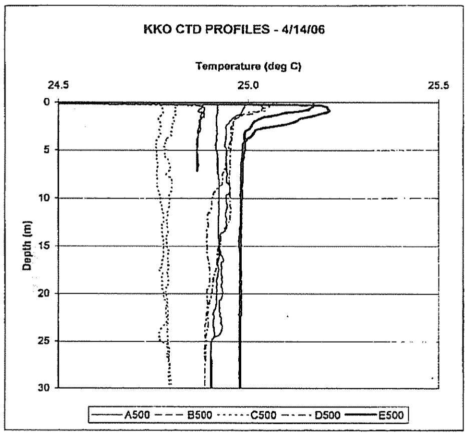
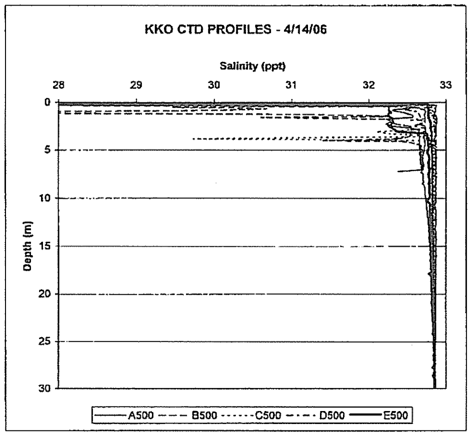
30
D50
D100
D500


KKO CTD PROFILES - 4/14/06
Temperature (deg C)
Depth (m)
A500 B500 C500 D500 E500


KKO CTD PROFILES - 4/14/06
Salinity (ppt)
Depth (m)
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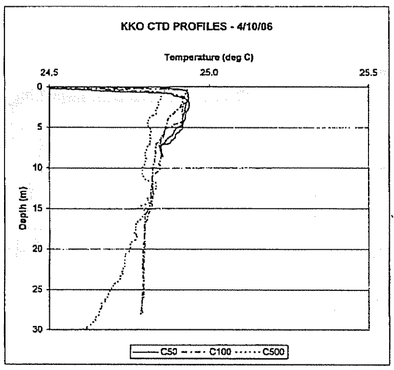
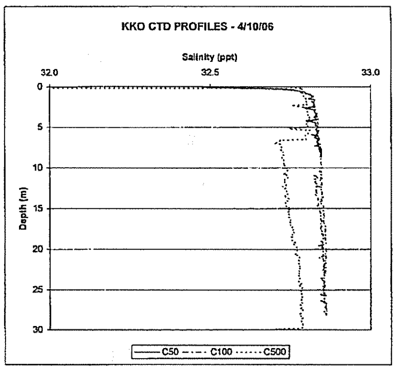
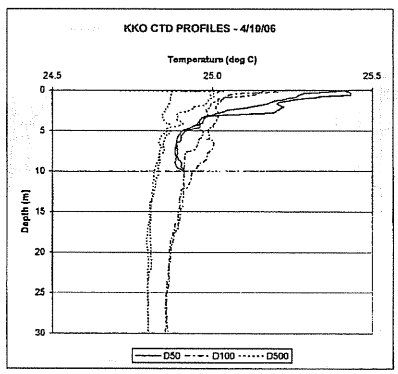
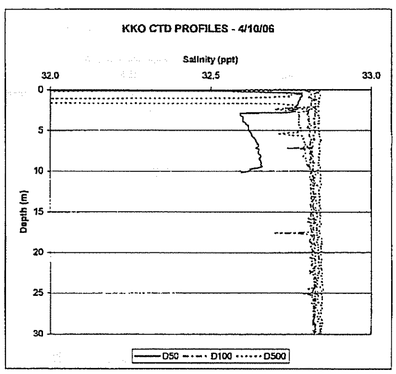

KKO CTD PROFILES - 4/10/06
Temperature (deg C)
Depth (m)
C50 C100 C500

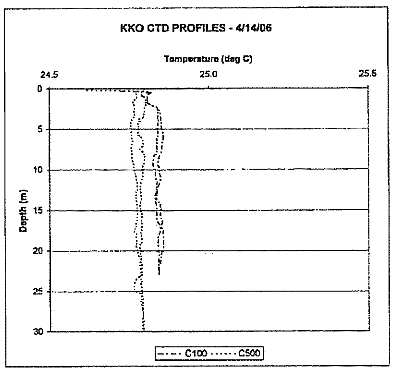

KKO CTD PROFILES - 4/10/06
Salinity (ppt)
Depth (m)
C50 C100 C500

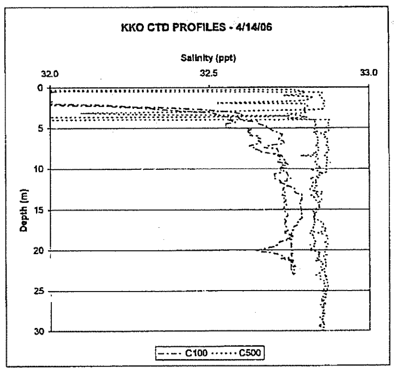

KKO CTD PROFILES - 4/10/06
Temperature (deg C)
Depth (m)
D50 D100 D500

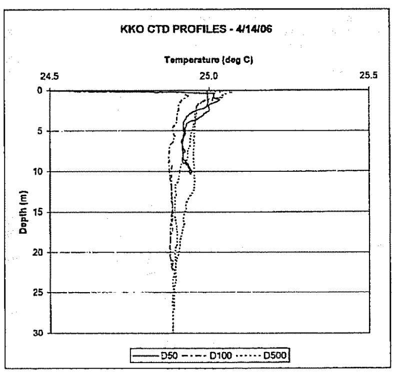

KKO CTD PROFILES - 4/10/06
Salinity (ppt)
Depth (m)
D50 D100 D500

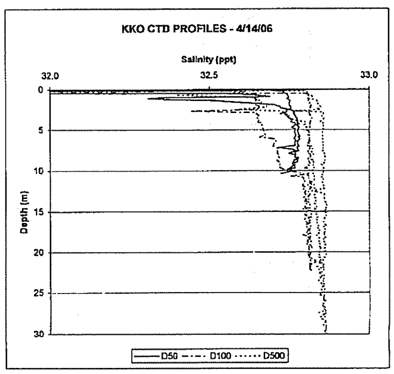
APPENDIX C

Percent bottom cover for photo-quadrats taken along nine biota monitoring transects within the Kona Kai Ola study area on April 3, 10 and 14, 2006.









Appendic B. Percent bottom cover for photo-quadrats taken along biota monitoring transects at nine stations within the Kona Kai Ola study area.. Transect locations are shown in Figure 3. Data are results of 200 point analyses of photos of 0.6 x 1.0 m quadrats.

		Sand	Rubble	Rock	*Porites lobata*	dead *P. lobata*	*Porites compressa*	dead *P. compressa*	*Pocillopora meandrina*	dead *P. meandrina*	*Montipora capitata*	*Montipora flabellata*	*Montipora patula*	*Pavona varians*	*Leptastria purpurea*	*Ralfsia* sp.	*Halimeda*	Coralline algae	*Asparagopsis taxiformis*	*A. edmonsoni*
B1	Shallow																			
	1	0.0%	25.0%	44.0%	27.5%	2.5%	0.0%	0.0%	0.0%	0.0%	1.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	2	0.0%	0.0%	83.5%	14.0%	2.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	3	0.0%	1.5%	57.0%	38.0%	3.0%	0.0%	0.0%	0.0%	0.0%	0.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	4	0.0%	0.0%	92.0%	3.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	5.0%	0.0%	0.0%
	5	0.0%	0.0%	64.0%	33.5%	2.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	6	0.0%	0.0%	21.0%	56.5%	22.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	7	0.0%	0.0%	57.5%	34.0%	8.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	8	1.0%	13.5%	23.0%	58.5%	3.0%	0.0%	0.0%	1.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	9	0.0%	3.5%	80.5%	15.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.5%	0.0%	0.0%	0.0%	0.0%	0.0%
	10	0.0%	0.0%	24.5%	60.0%	15.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	Mean	0.1%	4.4%	54.7%	34.1%	6.0%	0.0%	0.0%	0.1%	0.0%	0.2%	0.0%	0.0%	0.0%	0.1%	0.0%	0.0%	0.5%	0.0%	0.0%
B2	Middle																			
	1	0.0%	3.0%	40.0%	43.5%	12.5%	1.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	2	1.5%	0.0%	30.5%	52.5%	14.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	1.0%	0.0%	0.0%	0.0%	0.0%
	3	4.0%	8.0%	68.5%	19.0%	0.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	4	0.0%	0.0%	38.5%	36.5%	17.0%	0.0%	0.0%	0.5%	5.5%	2.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	5	1.5%	3.0%	21.5%	70.0%	4.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	6	13.0%	2.5%	48.5%	33.0%	3.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	7	11.0%	0.5%	12.5%	36.5%	26.5%	1.0%	0.0%	12.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	8	2.5%	4.5%	11.0%	55.5%	21.5%	2.0%	0.0%	0.0%	3.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	9	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	10	0.0%	0.0%	68.5%	28.0%	1.5%	1.0%	0.0%	0.0%	0.0%	1.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	Mean	3.4%	2.2%	34.0%	37.5%	10.1%	0.5%	0.0%	1.3%	0.9%	0.3%	0.0%	0.0%	0.0%	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%
B3	Deep																			
	1	0.5%	1.5%	0.0%	54.0%	18.5%	22.5%	2.5%	0.0%	0.0%	0.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	2	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	3	0.0%	17.5%	73.5%	7.5%	1.0%	0.0%	0.0%	0.0%	0.0%	0.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	4	1.5%	7.5%	38.0%	30.0%	9.5%	10.5%	3.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	5	11.5%	78.5%	8.0%	1.0%	0.0%	0.0%	0.0%	0.0%	0.0%	1.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	6	5.0%	16.5%	17.5%	32.5%	12.5%	13.5%	2.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	7	4.5%	50.5%	6.5%	14.0%	8.0%	16.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	8	0.0%	41.5%	46.0%	4.5%	7.0%	1.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	9	0.0%	0.0%	43.0%	36.5%	12.5%	4.0%	4.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	10	3.5%	60.0%	33.0%	2.5%	1.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	Mean	2.7%	27.4%	26.6%	18.3%	7.0%	6.8%	1.2%	0.0%	0.0%	0.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%

Appendic B. Percent bottom cover for photo-quadrats taken along biota monitoring transects at nine stations within the Kona Kai Ola study area.. Transect locations are shown in Figure 3. Data are results of 200 point analyses of photos of 0.6 x 1.0 m quadrats.

		Sand	Rubble	Rock	*Porites lobata*	dead *P. lobata*	*Porites compressa*	dead *P. compressa*	*Pocillopora meandrina*	dead *P. meandrina*	*Montipora capitata*	*Montipora flabellata*	*Montipora patula*	*Pavona varians*	*Leptastria purpurea*	*Ralfsia* sp.	*Halimeda*	Coralline algae	*Asparagopsis taxiformis*	*A. edmonsoni*
A1	Shallow																			
	1	0.0%	1.0%	46.0%	14.0%	0.0%	0.0%	0.0%	23.0%	16.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	2	0.0%	0.0%	64.0%	7.0%	0.0%	0.0%	0.0%	4.0%	23.5%	1.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	3	0.0%	0.0%	72.5%	10.0%	1.0%	0.0%	0.0%	10.0%	1.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	5.0%	0.0%	0.0%
	4	0.0%	0.0%	62.5%	7.0%	0.0%	0.0%	0.0%	1.0%	29.0%	0.0%	0.0%	0.0%	0.0%	0.5%	0.0%	0.0%	0.0%	0.0%	0.0%
	5	0.0%	0.0%	13.0%	82.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	5.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	6	0.0%	0.0%	64.5%	7.0%	0.0%	0.0%	0.0%	17.0%	11.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	7	0.0%	6.0%	45.5%	14.0%	0.0%	0.0%	0.0%	14.0%	20.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	8	0.0%	3.5%	64.0%	5.0%	0.0%	0.0%	0.0%	17.5%	9.0%	0.0%	0.0%	1.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	9	0.0%	0.0%	70.0%	4.0%	0.0%	0.0%	0.0%	16.5%	9.0%	0.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	10	0.0%	0.0%	95.5%	2.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	2.5%	0.0%	0.0%
	Mean	0.0%	1.1%	59.8%	15.2%	0.1%	0.0%	0.0%	10.3%	12.0%	0.2%	0.0%	0.6%	0.0%	0.1%	0.0%	0.0%	0.8%	0.0%	0.0%
A2	Middle																			
	1	0.0%	0.0%	88.5%	3.0%	0.0%	0.0%	0.0%	8.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	2	0.0%	3.5%	96.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	3	0.0%	0.0%	82.5%	7.0%	0.0%	0.0%	0.0%	7.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	3.0%	0.0%	0.0%
	4	0.0%	0.0%	83.0%	7.0%	0.0%	0.0%	0.0%	6.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	3.5%	0.0%	0.0%
	5	0.0%	0.0%	88.5%	7.0%	0.0%	0.0%	0.0%	4.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	6	0.0%	0.0%	89.5%	1.0%	0.0%	0.0%	0.0%	6.5%	1.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	1.5%	0.0%	0.0%
	7	0.0%	0.0%	77.0%	1.0%	0.0%	0.0%	0.0%	19.0%	3.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	8	13.0%	0.0%	59.5%	4.0%	0.0%	0.0%	0.0%	7.0%	16.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	9	16.0%	0.0%	49.5%	1.5%	0.0%	0.0%	0.0%	16.5%	16.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	10	6.0%	0.0%	84.5%	0.0%	0.0%	0.0%	0.0%	6.0%	3.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	Mean	3.5%	0.4%	79.9%	3.2%	0.0%	0.0%	0.0%	8.2%	4.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.8%	0.0%	0.0%
A3	Deep																			
	1	0.0%	0.0%	98.0%	2.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	2	0.0%	0.0%	92.5%	7.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	3	0.0%	5.0%	91.0%	3.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	4	0.0%	56.5%	43.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	5	0.0%	71.0%	29.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	6	21.5%	44.5%	30.5%	0.0%	0.0%	3.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	7	8.5%	0.0%	86.0%	5.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	8	0.0%	5.0%	92.0%	3.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	9	0.0%	0.0%	91.5%	7.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	1.5%	0.0%	0.0%
	10	1.5%	2.0%	86.5%	7.5%	0.0%	0.0%	0.0%	1.5%	0.0%	0.0%	0.0%	0.0%	1.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	Mean	3.2%	18.4%	74.1%	3.6%	0.0%	0.4%	0.0%	0.2%	0.0%	0.1%	0.0%	0.0%	0.1%	0.0%	0.0%	0.0%	0.2%	0.0%	0.0%

Appendic B. Percent bottom cover for photo-quadrats taken along biota monitoring transects at nine stations within the Kona Kai Ola study area.. Transect locations are shown in Figure 3. Data are results of 200 point analyses of photos of 0.6 x 1.0 m quadrats.

		Sand	Rubble	Rock	*Porites lobata*	dead *P. lobata*	*Porites compressa*	dead *P. compressa*	*Pocillopora meandrina*	dead *P. meandrina*	*Montipora capitata*	*Montipora flabellata*	*Montipora patula*	*Pavona varians*	*Leptastria purpurea*	*Ralfsia* sp.	Halimeda	Corraline algae	*Asparagopsis taxiformis*	*A. edmonsoni*
D1	Shallow																			
	1	0.0%	0.0%	65.0%	35.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	2	0.0%	0.0%	65.5%	34.0%	0.0%	0.0%	0.0%	0.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	3	0.0%	0.0%	79.5%	8.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	12.5%
	4	0.0%	0.0%	52.5%	35.5%	2.0%	0.0%	0.0%	2.5%	0.0%	1.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	5	0.0%	0.0%	63.5%	32.0%	4.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	6	0.0%	0.0%	75.0%	16.5%	7.0%	0.0%	0.0%	0.5%	1.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	7	0.0%	0.0%	45.5%	0.0%	0.0%	0.0%	0.0%	7.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	47.0%
	8	0.0%	0.0%	66.0%	13.0%	0.0%	0.0%	0.0%	11.0%	10.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	9	0.0%	0.0%	65.0%	22.5%	0.0%	0.0%	0.0%	12.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	10	0.0%	0.0%	65.0%	1.0%	0.0%	0.0%	0.0%	11.5%	7.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	15.5%
	Mean	0.0%	0.0%	64.3%	19.8%	1.4%	0.0%	0.0%	4.6%	1.8%	0.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	7.5%
D2	Middle																			
	1	0.0%	0.0%	0.0%	76.5%	9.0%	11.0%	3.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	2	0.0%	7.0%	70.0%	14.5%	0.5%	0.0%	0.0%	4.0%	4.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	3	0.0%	0.0%	0.0%	39.5%	5.0%	53.0%	2.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	4	3.0%	28.5%	4.0%	35.5%	0.0%	29.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	5	0.0%	0.0%	4.0%	77.5%	10.0%	7.5%	1.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	6	2.0%	0.0%	0.0%	47.5%	11.5%	31.5%	7.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	7	10.5%	71.0%	11.0%	7.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	8	42.0%	34.0%	22.5%	1.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	9	0.0%	0.0%	74.5%	24.0%	1.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	10	0.5%	0.0%	76.5%	18.0%	5.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	Mean	5.8%	14.1%	26.3%	34.2%	4.3%	13.2%	1.5%	0.4%	0.4%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
D3	Deep																			
	1	1.0%	3.5%	16.0%	37.0%	16.0%	22.0%	4.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	2	0.0%	0.0%	0.0%	51.0%	0.0%	30.5%	3.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	15.5%	0.0%
	3	0.0%	0.0%	0.0%	13.5%	5.0%	69.5%	12.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	4	10.5%	0.0%	0.0%	22.0%	0.0%	57.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	10.0%	0.0%
	5	2.5%	46.0%	0.5%	16.0%	2.0%	27.5%	0.0%	0.0%	0.0%	1.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	3.5%	0.0%
	6	1.5%	4.5%	8.5%	31.0%	13.0%	32.0%	6.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	3.5%	0.0%
	7	0.5%	0.0%	0.0%	87.5%	3.0%	9.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	8	0.0%	0.0%	3.0%	0.5%	0.0%	83.0%	2.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	11.5%	0.0%
	9	4.0%	23.0%	7.0%	20.0%	17.5%	22.5%	6.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	10	0.0%	0.0%	0.0%	38.0%	6.5%	37.5%	15.5%	2.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.5%	0.0%
	Mean	2.0%	7.7%	3.5%	31.7%	6.3%	39.1%	4.9%	0.2%	0.0%	0.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	4.5%	0.0%

Appendic B. Percent bottom cover for photo-quadrats taken along biota monitoring transects at nine stations within the Kona Kai Ola study area.. Transect locations are shown in Figure 3. Data are results of 200 point analyses of photos of 0.6 x 1.0 m quadrats.

		Sand	Rubble	Rock	*Porites lobata*	dead *P. lobata*	*Porites compressa*	dead *P. compressa*	*Pocillopora meandrina*	dead *P. meandrina*	*Montipora capitata*	*Montipora flabellata*	*Montipora patula*	*Pavona varians*	*Leptastria purpurea*	*Ralfsia* sp.	Halimeda	Corraline algae	*Asparagopsis taxiformis*	*A. edmonsoni*
C1	Shallow																			
	1	0.0%	0.0%	50.0%	50.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	2	0.0%	0.0%	68.0%	32.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	3	0.0%	0.0%	69.0%	31.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	4	0.0%	0.0%	90.0%	8.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	2.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	5	0.0%	0.0%	90.0%	10.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	6	0.0%	0.0%	88.0%	10.5%	0.0%	0.0%	0.0%	0.0%	0.0%	1.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	7	0.0%	0.0%	85.5%	14.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	8	0.0%	0.0%	77.5%	8.0%	0.0%	0.0%	0.0%	0.0%	14.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	9	0.0%	0.0%	97.5%	2.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	10	0.0%	0.0%	72.5%	24.0%	0.0%	3.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	Mean	0.0%	0.0%	78.8%	19.0%	0.0%	0.4%	0.0%	0.0%	1.5%	0.2%	0.0%	0.0%	0.0%	0.2%	0.0%	0.0%	0.0%	0.0%	0.0%
C2	Middle																			
	1	9.5%	3.0%	13.5%	74.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	2	0.0%	0.0%	50.0%	50.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	3	0.0%	0.0%	95.0%	5.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	4	0.0%	0.0%	84.5%	13.5%	0.0%	2.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	5	0.0%	0.0%	87.0%	11.0%	0.0%	2.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	6	0.0%	0.0%	76.5%	16.5%	0.0%	4.0%	3.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	7	0.0%	5.5%	81.0%	3.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	8	0.0%	0.0%	99.5%	0.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	9	0.0%	14.0%	86.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	10	0.0%	0.0%	38.5%	61.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	Mean	1.0%	2.3%	72.2%	23.5%	0.0%	0.8%	0.3%	0.0%	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
C3	Deep																			
	1	2.0%	0.0%	89.5%	8.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	2	9.5%	3.0%	80.5%	2.5%	0.0%	0.0%	0.0%	0.0%	4.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	3	7.0%	2.0%	84.5%	6.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	4	0.0%	0.0%	94.0%	6.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	5	0.0%	0.0%	96.5%	0.0%	0.0%	3.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	6	18.5%	3.5%	77.5%	0.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	7	8.5%	5.0%	86.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	8	0.0%	0.0%	98.0%	2.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	9	0.0%	0.0%	100.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	10	8.5%	9.0%	82.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	Mean	5.4%	2.3%	89.0%	2.6%	0.0%	0.4%	0.0%	0.0%	0.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%

Appendic B. Percent bottom cover for photo-quadrats taken along biota monitoring transects at nine stations within the Kona Kai Ola study area.. Transect locations are shown in Figure 3. Data are results of 200 point analyses of photos of 0.6 x 1.0 m quadrats.

		Sand	Rubble	Rock	*Porites lobata*	dead *P. lobata*	*Porites compressa*	dead *P. compressa*	*Pocillopora meandrina*	dead *P. meandrina*	*Montipora capitata*	*Montipora flabellata*	*Montipora patula*	*Pavona varians*	*Leptastria purpurea*	*Ralfsia* sp.	Halimeda	Corraline algae	*Asparagopsis taxiformis*	*A. edmonsoni*
F1	Shallow																			
	1	0.0%	0.0%	97.0%	0.0%	0.0%	0.0%	0.0%	0.0%	2.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	1.0%	0.0%	0.0%
	2	2.0%	0.0%	95.5%	2.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.5%	0.0%	0.0%
	3	0.0%	0.0%	83.0%	6.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	10.0%	0.0%	0.0%	0.0%	1.0%	0.0%	0.0%
	4	0.0%	0.0%	88.0%	0.0%	0.0%	0.0%	0.0%	2.5%	2.0%	0.0%	0.0%	0.0%	0.0%	0.5%	0.0%	0.0%	7.0%	0.0%	0.0%
	5	0.0%	0.0%	63.0%	2.0%	0.0%	0.0%	0.0%	19.0%	1.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	14.5%	0.0%	0.0%
	6	0.0%	0.0%	79.5%	1.0%	0.0%	0.0%	0.0%	8.5%	4.5%	2.0%	0.0%	0.0%	4.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	7	0.0%	0.0%	80.0%	10.5%	0.0%	0.0%	0.0%	4.0%	5.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	8	0.0%	0.0%	80.5%	0.0%	0.0%	0.0%	0.0%	12.5%	1.5%	0.0%	0.0%	0.0%	0.0%	3.5%	0.0%	0.0%	2.0%	0.0%	0.0%
	9	0.0%	0.0%	57.5%	36.0%	3.5%	0.0%	0.0%	0.0%	2.5%	0.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	10	0.0%	0.0%	76.0%	0.5%	0.0%	0.0%	0.0%	11.0%	8.0%	0.0%	0.0%	0.0%	0.0%	1.5%	0.0%	0.0%	3.0%	0.0%	0.0%
	Mean	0.2%	0.0%	80.0%	5.8%	0.4%	0.0%	0.0%	5.8%	2.8%	0.3%	0.0%	0.0%	1.5%	0.6%	0.0%	0.0%	2.9%	0.0%	0.0%
F2	Middle																			
	1	0.0%	0.0%	78.5%	17.0%	2.5%	0.0%	0.0%	0.5%	0.0%	1.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.5%
	2	0.0%	4.0%	24.5%	47.0%	22.5%	0.0%	0.0%	0.5%	0.0%	1.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	3	0.5%	0.5%	63.5%	26.0%	7.0%	0.0%	0.0%	0.0%	0.0%	2.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.5%
	4	0.0%	0.0%	61.0%	27.0%	9.5%	0.0%	0.0%	0.0%	0.0%	2.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	5	0.0%	0.0%	72.5%	14.5%	1.5%	0.0%	0.0%	9.0%	2.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	6	0.0%	0.0%	80.0%	7.5%	1.0%	0.0%	0.0%	4.0%	0.0%	7.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	7	6.0%	23.0%	28.5%	19.0%	0.0%	0.0%	0.0%	13.0%	5.5%	5.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	8	1.0%	0.5%	11.0%	26.0%	22.5%	8.0%	5.0%	23.5%	2.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	9	0.0%	2.5%	44.0%	17.0%	13.0%	0.0%	0.0%	13.0%	10.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	10	0.0%	0.0%	65.5%	5.5%	4.5%	0.0%	0.0%	24.0%	0.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	Mean	0.8%	3.1%	52.9%	20.7%	8.4%	0.8%	0.5%	8.8%	2.2%	2.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%
F3	Deep																			
	1	0.0%	10.0%	75.5%	8.5%	0.0%	0.0%	0.0%	0.0%	0.0%	1.0%	0.0%	0.0%	0.0%	0.0%	5.0%	0.0%	0.0%	0.0%	0.0%
	2	0.0%	1.5%	5.0%	14.0%	76.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	3.0%	0.0%	0.0%	0.0%	0.0%
	3	0.0%	44.0%	40.5%	10.0%	2.0%	0.0%	0.0%	0.0%	0.0%	1.0%	0.0%	0.0%	0.0%	0.0%	2.5%	0.0%	0.0%	0.0%	0.0%
	4	2.0%	23.5%	63.5%	7.5%	0.5%	0.5%	0.0%	0.0%	0.0%	2.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	5	0.0%	1.0%	27.0%	28.5%	17.5%	16.0%	8.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	1.5%	0.0%	0.0%	0.0%	0.0%
	6	0.0%	0.5%	13.0%	4.5%	6.0%	51.5%	24.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	7	0.0%	14.0%	5.0%	11.0%	21.5%	29.0%	15.0%	0.0%	1.5%	0.0%	0.0%	0.0%	0.0%	0.0%	2.0%	0.0%	1.0%	0.0%	0.0%
	8	0.0%	46.5%	0.0%	21.5%	2.5%	18.5%	9.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	1.5%	0.0%	0.5%	0.0%	0.0%
	9	0.5%	8.5%	88.0%	2.5%	0.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	10	2.0%	0.0%	97.0%	1.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	Mean	0.5%	15.0%	41.5%	10.9%	12.7%	11.6%	5.7%	0.0%	0.2%	0.4%	0.0%	0.0%	0.0%	0.0%	1.6%	0.0%	0.2%	0.0%	0.0%

Appendic B. Percent bottom cover for photo-quadrats taken along biota monitoring transects at nine stations within the Kona Kai Ola study area.. Transect locations are shown in Figure 3. Data are results of 200 point analyses of photos of 0.6 x 1.0 m quadrats.

		Sand	Rubble	Rock	*Porites lobata*	dead *P. lobata*	*Porites compressa*	dead *P. compressa*	*Pocillopora meandrina*	dead *P. meandrina*	*Montipora capitata*	*Montipora flabellata*	*Montipora patula*	*Pavona varians*	*Leptastria purpurea*	*Ralfsia* sp.	Halimeda	Corraline algae	*Asparagopsis taxiformis*	*A. edmonsoni*
E1	Shallow																			
	1	0.0%	0.0%	56.5%	43.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	2	0.0%	0.0%	50.5%	49.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	3	0.0%	0.0%	39.5%	60.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	4	0.0%	0.0%	43.5%	55.0%	0.0%	0.0%	0.0%	0.0%	0.0%	1.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	5	0.0%	0.0%	52.0%	47.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	1.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	6	0.0%	0.0%	57.5%	42.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	7	0.0%	0.0%	10.0%	90.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	8	0.0%	0.0%	64.5%	35.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	9	0.0%	0.0%	15.0%	85.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	10	0.0%	0.0%	29.5%	70.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	Mean	0.0%	0.0%	41.9%	57.9%	0.0%	0.0%	0.0%	0.0%	0.0%	0.2%	0.0%	0.0%	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%
E2	Middle																			
	1	0.0%	0.0%	14.5%	37.5%	1.0%	38.5%	7.0%	1.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	2	0.0%	0.0%	8.0%	38.0%	3.5%	40.0%	10.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	3	0.0%	0.0%	3.0%	30.5%	0.0%	60.0%	6.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	4	0.0%	0.0%	10.5%	26.0%	3.0%	51.5%	8.0%	0.0%	0.0%	1.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	5	30.0%	3.5%	6.0%	54.0%	0.0%	6.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	6	0.0%	0.0%	1.5%	38.5%	0.0%	54.5%	2.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	3.0%
	7	0.0%	0.0%	2.5%	29.5%	11.5%	52.0%	4.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	8	0.0%	0.0%	6.5%	53.0%	6.5%	34.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	9	0.0%	0.0%	9.0%	52.0%	1.5%	29.5%	8.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	10	0.0%	0.0%	0.0%	56.5%	4.0%	38.0%	1.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	Mean	3.0%	0.4%	6.2%	41.6%	3.1%	40.5%	4.9%	0.2%	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.3%
E3	Deep																			
	1	0.0%	0.0%	14.0%	30.5%	1.5%	40.5%	13.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	2	0.0%	0.0%	1.0%	76.5%	1.0%	13.5%	4.5%	3.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	3	0.0%	0.0%	5.5%	89.5%	5.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	4	3.0%	0.0%	3.5%	59.5%	10.0%	17.5%	6.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	5	0.0%	0.0%	20.0%	58.0%	0.5%	21.0%	0.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	6	5.5%	6.0%	14.5%	21.5%	2.0%	46.5%	5.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	7	0.0%	0.0%	9.0%	46.5%	0.0%	26.5%	18.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	8	0.0%	0.0%	7.0%	80.0%	2.5%	10.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	9	0.0%	0.0%	12.0%	76.0%	1.5%	10.0%	0.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	10	100.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	Mean	10.9%	0.5%	8.7%	53.8%	2.4%	18.6%	4.9%	0.4%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%

Appendic B. Percent bottom cover for photo-quadrats taken along biota monitoring transects at nine stations within the Kona Kai Ola study area.. Transect locations are shown in Figure 3. Data are results of 200 point analyses of photos of 0.6 x 1.0 m quadrats.

		Sand	Rubble	Rock	*Porites lobata*	dead *P. lobata*	*Porites compressa*	dead *P. compressa*	*Pocillopora meandrina*	dead *P. meandrina*	*Montipora capitata*	*Montipora flabellata*	*Montipora patula*	*Pavona varians*	*Leptastria purpurea*	*Ralfsia* sp.	*Halimeda*	Corraline algae	*Asparagopsis taxiformis*	*A. edmonsoni*
H-1	Shallow																			
	1	9.0%	13.5%	38.0%	13.0%	0.0%	26.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	2	3.0%	26.5%	3.5%	51.0%	0.0%	9.0%	0.0%	0.0%	3.0%	0.0%	0.0%	0.0%	0.0%	4.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	3	0.5%	28.5%	57.5%	0.0%	0.0%	1.0%	0.0%	4.0%	8.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	4	0.0%	60.0%	34.0%	0.0%	0.0%	6.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	5	5.0%	18.0%	56.5%	2.5%	0.0%	7.0%	0.0%	0.5%	10.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	6	2.0%	1.5%	65.0%	0.5%	0.0%	12.0%	0.0%	1.5%	17.0%	0.0%	0.0%	0.0%	0.0%	0.5%	0.0%	0.0%	0.0%	0.0%	0.0%
	7	8.5%	24.5%	23.5%	0.0%	0.0%	25.5%	0.0%	0.0%	11.0%	0.0%	4.0%	0.0%	0.0%	2.5%	0.0%	0.0%	0.0%	0.0%	0.5%
	8	3.0%	6.0%	14.5%	16.5%	0.0%	59.0%	0.0%	0.0%	1.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	9	5.0%	5.0%	18.5%	16.0%	0.0%	54.5%	0.0%	0.0%	1.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	10	11.0%	33.5%	51.5%	0.0%	0.0%	1.0%	0.0%	3.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	Mean	4.7%	21.7%	36.3%	10.0%	0.0%	20.2%	0.0%	0.9%	5.2%	0.0%	0.4%	0.0%	0.0%	0.7%	0.0%	0.0%	0.0%	0.0%	0.1%
H-2	Middle																			
	1	0.0%	0.0%	18.5%	35.0%	0.0%	26.0%	0.0%	0.0%	12.0%	0.0%	0.0%	0.0%	0.0%	8.5%	0.0%	0.0%	0.0%	0.0%	0.0%
	2	0.0%	26.5%	56.5%	6.5%	0.0%	1.5%	0.0%	0.0%	7.5%	0.0%	0.0%	0.0%	0.0%	1.5%	0.0%	0.0%	0.0%	0.0%	0.0%
	3	0.0%	18.0%	71.5%	0.0%	0.0%	3.0%	1.0%	0.0%	0.0%	0.0%	0.0%	2.5%	0.0%	4.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	4	0.0%	0.0%	31.5%	25.5%	0.0%	13.5%	0.0%	0.0%	28.0%	0.0%	0.0%	0.0%	0.0%	0.5%	0.0%	1.0%	0.0%	0.0%	0.0%
	5	0.0%	0.0%	35.0%	31.0%	0.0%	23.0%	0.0%	0.0%	0.0%	0.0%	0.0%	8.0%	0.0%	1.5%	0.0%	1.5%	0.0%	0.0%	0.0%
	6	1.5%	0.0%	41.0%	7.0%	0.0%	49.5%	0.0%	0.0%	1.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	7	0.0%	0.0%	65.0%	10.0%	0.0%	14.5%	0.0%	1.0%	9.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	8	0.0%	0.0%	38.0%	17.5%	0.0%	41.5%	0.0%	0.0%	0.0%	0.0%	0.0%	3.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	9	1.0%	0.0%	24.0%	18.0%	0.0%	57.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	10	0.0%	12.5%	0.0%	9.5%	29.5%	20.5%	21.0%	0.0%	4.5%	0.0%	0.0%	2.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	Mean	0.3%	5.7%	38.1%	16.0%	3.0%	25.0%	2.2%	0.1%	6.3%	0.0%	0.0%	1.6%	0.0%	1.6%	0.0%	0.3%	0.0%	0.0%	0.0%
H-3	Deep																			
	1	0.0%	1.0%	3.5%	42.5%	16.5%	15.5%	21.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	2	2.5%	14.0%	3.0%	24.0%	32.5%	10.0%	14.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	3	23.0%	42.0%	0.0%	0.0%	11.5%	0.0%	13.0%	1.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	9.5%	0.0%
	4	9.0%	82.5%	0.0%	3.0%	0.0%	4.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	1.0%	0.0%
	5	2.5%	0.0%	0.0%	15.0%	0.5%	66.0%	14.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	1.5%	0.0%	0.0%	0.0%
	6	13.0%	87.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	7	8.5%	84.5%	1.5%	4.5%	0.0%	1.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	8	4.0%	88.5%	5.5%	0.0%	0.0%	2.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	9	3.0%	72.0%	22.0%	0.0%	0.0%	3.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	10	3.0%	76.0%	13.5%	0.0%	0.0%	7.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	Mean	6.9%	54.8%	4.9%	8.9%	6.1%	11.0%	6.3%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.2%	0.0%	1.1%	0.0%

Appendic B. Percent bottom cover for photo-quadrats taken along biota monitoring transects at nine stations within the Kona Kai Ola study area.. Transect locations are shown in Figure 3. Data are results of 200 point analyses of photos of 0.6 x 1.0 m quadrats.

		Sand	Rubble	Rock	*Porites lobata*	dead *P. lobata*	*Porites compressa*	dead *P. compressa*	*Pocillopora meandrina*	dead *P. meandrina*	*Montipora capitata*	*Montipora flabellata*	*Montipora patula*	*Pavona varians*	*Leptastria purpurea*	*Ralfsia* sp.	*Halimeda*	Corraline algae	*Asparagopsis taxiformis*	*A. edmonsoni*
G-1	Shallow																			
	1	0.0%	0.0%	77.0%	0.0%	0.0%	21.5%	0.0%	0.0%	1.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	2	3.5%	0.0%	63.5%	0.0%	0.0%	9.5%	0.0%	0.0%	3.0%	0.0%	0.0%	0.0%	0.0%	20.5%	0.0%	0.0%	0.0%	0.0%	0.0%
	3	0.0%	0.0%	71.0%	0.0%	0.0%	18.5%	0.0%	0.0%	7.0%	3.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	4	0.0%	0.0%	74.0%	0.0%	0.0%	5.0%	0.0%	0.0%	16.5%	0.0%	0.0%	0.0%	0.0%	4.5%	0.0%	0.0%	0.0%	0.0%	0.0%
	5	0.0%	0.0%	65.5%	0.0%	0.0%	0.5%	0.0%	0.0%	20.5%	0.0%	0.0%	0.0%	0.0%	13.5%	0.0%	0.0%	0.0%	0.0%	0.0%
	6	0.0%	0.0%	83.5%	2.0%	0.0%	6.0%	0.0%	1.5%	0.0%	0.0%	0.0%	0.0%	0.0%	7.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	7	0.0%	0.0%	81.5%	0.0%	0.0%	18.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	8	0.0%	0.0%	94.0%	0.0%	0.0%	1.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	4.5%	0.0%	0.0%	0.0%
	9	0.0%	0.0%	45.0%	8.5%	0.0%	20.5%	0.0%	1.0%	0.0%	0.0%	0.0%	0.0%	0.0%	25.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	10	0.0%	0.0%	45.0%	0.0%	0.0%	24.0%	0.0%	0.0%	11.0%	0.0%	0.0%	0.0%	0.0%	20.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	Mean	0.4%	0.0%	70.0%	1.1%	0.0%	12.6%	0.0%	0.3%	6.0%	0.4%	0.0%	0.0%	0.0%	9.1%	0.0%	0.5%	0.0%	0.0%	0.0%
G-2	Middle																			
	1	0.0%	0.0%	61.0%	1.5%	0.0%	36.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	1.5%
	2	0.0%	0.0%	71.5%	9.0%	0.0%	17.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	2.5%	0.0%	0.0%	0.0%	0.0%	0.0%
	3	0.0%	0.0%	97.0%	0.0%	0.0%	3.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	4	0.0%	0.0%	68.5%	6.5%	0.0%	15.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	10.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	5	0.0%	0.0%	56.5%	11.0%	0.0%	24.5%	0.0%	0.0%	7.0%	0.0%	0.0%	0.0%	0.0%	1.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	6	0.0%	0.0%	69.5%	3.0%	0.0%	20.5%	0.0%	0.0%	7.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	7	0.0%	0.0%	73.0%	3.5%	0.0%	22.0%	0.0%	1.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	8	0.0%	0.0%	50.5%	8.0%	0.0%	23.0%	0.0%	2.0%	8.0%	0.0%	0.0%	0.0%	0.0%	8.5%	0.0%	0.0%	0.0%	0.0%	0.0%
	9	0.0%	0.0%	74.0%	0.0%	0.0%	13.0%	0.0%	1.0%	7.5%	0.0%	0.0%	0.0%	0.0%	4.5%	0.0%	0.0%	0.0%	0.0%	0.0%
	10	0.5%	7.0%	54.0%	4.0%	0.0%	17.0%	1.0%	0.0%	10.0%	0.0%	0.0%	0.0%	0.0%	6.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	Mean	0.1%	0.7%	67.6%	4.7%	0.0%	19.1%	0.1%	0.5%	4.0%	0.0%	0.0%	0.0%	0.0%	3.3%	0.0%	0.0%	0.0%	0.0%	0.2%
G-3	Deep																			
	1	0.0%	0.0%	98.0%	0.0%	0.0%	2.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	2	11.5%	2.5%	76.0%	0.0%	0.0%	1.0%	2.5%	1.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	5.0%	0.0%
	3	3.5%	0.5%	66.0%	0.0%	0.0%	0.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	29.5%	0.0%
	4	7.5%	16.0%	58.5%	0.0%	0.0%	1.0%	0.0%	1.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	15.0%	0.0%
	5	1.5%	6.5%	80.0%	0.0%	0.0%	12.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	6	0.0%	0.0%	91.0%	0.0%	0.0%	4.0%	1.5%	1.0%	0.0%	0.0%	0.0%	0.0%	0.0%	2.5%	0.0%	0.0%	0.0%	0.0%	0.0%
	7	0.0%	1.5%	89.5%	0.0%	0.0%	5.5%	1.5%	0.0%	0.0%	0.0%	0.0%	2.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	8	0.0%	8.5%	38.5%	0.0%	7.5%	28.0%	15.5%	0.5%	0.0%	0.0%	0.0%	1.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	9	0.0%	0.0%	82.5%	0.0%	0.0%	13.0%	4.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.5%	0.0%	0.0%	0.0%
	10	0.0%	0.0%	67.0%	0.0%	0.0%	24.0%	9.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	Mean	2.4%	3.6%	74.7%	0.0%	0.8%	9.1%	3.4%	0.5%	0.0%	0.0%	0.0%	0.4%	0.0%	0.3%	0.0%	0.1%	0.0%	5.0%	0.0%

APPENDIX D

Results of quantitative fish surveys conducted along nine biota monitoring transects within the Kona Kai Ola study area on April 3, 10 and 14, 2006.

Appendic B. Percent bottom cover for photo-quadrats taken along biota monitoring transects at nine stations within the Kona Kai Ola study area.. Transect locations are shown in Figure 3. Data are results of 200 point analyses of photos of 0.6 x 1.0 m quadrats.

		Sand	Rubble	Rock	*Porites lobata*	dead *P. lobata*	*Porites compressa*	dead *P. compressa*	*Pocillopora meandrina*	dead *P. meandrina*	*Montipora capitata*	*Montipora flabellata*	*Montipora patula*	*Pavona varians*	*Leptastria purpurea*	*Ralfsia* sp.	Halimeda	Coralline algae	*Asparagopsis taxiformis*	*A. edmonsoni*
I-1	Shallow																			
	1	0.0%	0.0%	60.5%	0.5%	0.0%	7.0%	0.0%	0.0%	20.0%	0.0%	0.0%	0.0%	0.0%	12.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	2	0.0%	1.5%	60.5%	2.0%	0.0%	13.0%	0.0%	0.0%	19.0%	0.0%	0.0%	0.0%	0.0%	4.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	3	0.0%	0.0%	37.0%	0.0%	0.0%	5.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	9.0%	0.0%	0.0%	0.0%	0.0%	48.5%
	4	0.0%	0.0%	55.5%	0.0%	0.0%	7.0%	0.0%	0.0%	17.5%	0.0%	0.0%	0.0%	0.0%	20.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	5	0.0%	0.0%	73.5%	0.0%	0.0%	7.0%	0.0%	0.0%	10.0%	0.0%	0.0%	0.0%	0.0%	9.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	6	0.0%	3.0%	71.5%	0.0%	0.0%	9.0%	0.0%	0.0%	6.5%	0.0%	0.0%	0.0%	0.0%	10.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	7	0.0%	0.0%	43.0%	1.0%	0.0%	26.5%	0.0%	0.0%	12.5%	0.0%	0.0%	0.0%	0.0%	17.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	8	0.0%	10.5%	75.5%	0.0%	0.0%	9.5%	0.0%	0.0%	4.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	9	0.0%	0.0%	66.5%	0.0%	0.0%	5.0%	0.0%	0.0%	17.0%	0.0%	0.0%	0.0%	0.0%	11.5%	0.0%	0.0%	0.0%	0.0%	0.0%
	10	0.0%	0.0%	55.5%	0.0%	0.0%	10.5%	0.0%	4.5%	15.0%	0.0%	0.0%	0.0%	0.0%	13.5%	0.0%	0.0%	1.0%	0.0%	0.0%
	Mean	0.0%	1.5%	59.9%	0.4%	0.0%	10.0%	0.0%	0.5%	12.2%	0.0%	0.0%	0.0%	0.0%	10.6%	0.0%	0.0%	0.1%	0.0%	4.9%
I-2	Middle																			
	1	31.5%	6.0%	61.0%	0.0%	0.0%	1.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	2	18.0%	30.0%	42.5%	0.0%	0.0%	1.5%	0.0%	0.0%	8.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	3	18.0%	22.0%	47.5%	1.0%	0.0%	10.5%	0.0%	0.0%	1.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	4	0.0%	0.0%	47.5%	2.5%	0.0%	49.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	1.0%	0.0%	0.0%	0.0%
	5	0.0%	0.0%	44.0%	0.0%	0.0%	54.0%	2.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	6	14.0%	5.0%	61.0%	0.0%	2.0%	12.0%	5.0%	1.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	7	3.0%	41.0%	54.0%	0.0%	0.0%	1.5%	0.0%	0.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	8	0.0%	88.5%	0.0%	0.0%	0.0%	2.0%	0.0%	0.0%	9.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	9	0.0%	0.0%	35.0%	5.0%	0.0%	52.0%	1.0%	2.5%	0.5%	0.0%	0.0%	4.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	10	0.0%	0.0%	30.0%	0.0%	2.5%	19.0%	48.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	Mean	8.5%	19.3%	42.3%	0.9%	0.5%	20.3%	5.7%	0.4%	1.9%	0.0%	0.0%	0.4%	0.0%	0.0%	0.0%	0.1%	0.0%	0.0%	0.0%
I-3	Deep																			
	1	25.5%	0.0%	43.5%	0.0%	0.0%	28.5%	2.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	2	0.0%	0.0%	56.0%	0.0%	11.0%	7.0%	21.0%	0.0%	0.0%	0.0%	0.0%	5.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	3	0.0%	0.0%	63.0%	0.0%	0.5%	31.5%	4.5%	0.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	4	0.0%	5.5%	81.0%	2.0%	0.0%	11.0%	0.0%	0.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	5	0.0%	6.0%	45.0%	0.0%	5.5%	17.0%	23.5%	0.0%	0.0%	0.0%	0.0%	1.0%	0.0%	0.0%	0.0%	0.0%	0.0%	1.0%	1.0%
	6	0.0%	0.0%	11.5%	0.0%	3.5%	11.5%	65.5%	0.0%	0.0%	0.0%	0.0%	1.0%	0.0%	0.0%	0.0%	0.0%	0.0%	2.5%	4.0%
	7	0.0%	0.0%	14.5%	0.0%	5.0%	0.0%	73.5%	0.0%	0.0%	0.0%	0.0%	0.5%	0.0%	0.0%	0.0%	0.0%	0.0%	1.5%	5.0%
	8	0.0%	24.5%	35.0%	0.0%	5.0%	0.0%	32.0%	0.0%	0.0%	0.0%	0.0%	3.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	9	0.0%	0.0%	81.5%	0.0%	0.0%	12.5%	2.5%	0.0%	0.0%	0.0%	0.0%	3.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	10	0.0%	10.0%	59.0%	0.0%	0.0%	6.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	24.5%	0.0%
	Mean	2.6%	4.6%	49.0%	0.2%	3.1%	12.6%	22.5%	0.1%	0.0%	0.0%	0.0%	1.5%	0.0%	0.0%	0.0%	0.0%	0.0%	3.0%	1.0%

Appendix D.1. Abundance of fish observed along 25 m transects at sites located between Wawahiwaa Point and Kaiwi Point on April 4 - 13, 2006. Transect locations are shown in Figure 11. Species ordered by total abundance.

	Site A			Site B			Site C			Site D			Site E			Site F			Site G			Site H			Site I			TOTAL
Species	Shallow	Mid	Deep	Shallow	Mid	Deep	Shallow	Mid	Deep	Shallow	Mid	Deep	Shallow	Mid	Deep	Shallow	Mid	Deep	Shallow	Mid	Deep	Shallow	Mid	Deep	Shallow	Mid	Deep	
Plectroglyphidodon imparipenis	1			1				1		1																		4
Oxycheilinus unifasciatus												2		1										1				4
Pseudojuloides cerasinus									3															1				4
Scarus psittacus			1										1									1			1			4
Acanthurus dussumieri									1							3												4
Apogon kallopterus						3																						3
Alphareus furca																1				1			1					3
Parupeneus cyclostomus							2		1																			3
Parupeneus pleurostigma									1																		2	3
Chaetodon auriga			1							2																		3
Chaetodon lineolatus			2							1																		3
Chaetodon lunula										2									1									3
Forcipiger longirostris																			3									3
Hemiaurichthys thompsoni																										3		3
Acanthurus achilles													1										1			1		3
Melichthys niger					1														1	1								3
Ostracion meleagris				1				1								1												3
Aulostomus chinensis												1											1					2
Macropharyngodon geoffroy					1																	1		1				3
Scarus rubroviolaceus																									2			2
Cirripectes vanderbilti														1												1		2
Plagiotremus goslinei				1												1												2
Cantherhines dumerilii		1													1													2
Gymnothorax undulatus								1																				1
Sargocentron ensiferum															1													1
Fistularia commersonii															1													1
Cirrhitops fasciatus							1																					1
Caranx melampygus																		1										1
Lutjanus kasmira		1																										1
Anampses cuvier																						1						1
Exallias brevis																										1		1
Acanthurus guttatus																1												1
Acanthurus xanthopterus																				1								1
Sufflamen fraenatus									1																			1
Aluterus scriptus																									1			1
Pervagor aspricaudus																					1							1
Arothron meleagris						1																						1
Diodon histrix			1																									1
Calotomus zonarchus																			1									1
Centropyge loricula																							1					1
Anampses chrysocephalus																								1				1

Appendix D.1. Abundance of fish observed along 25 m transects at sites located between Wawahiwaa Point and Kaiwi Point on April 4 - 13, 2006. Transect locations are shown in Figure 11. Species ordered by total abundance.

	Site A			Site B			Site C			Site D			Site E			Site F			Site G			Site H			Site I			TOTAL
Species	Shallow	Mid	Deep	Shallow	Mid	Deep	Shallow	Mid	Deep	Shallow	Mid	Deep	Shallow	Mid	Deep	Shallow	Mid	Deep	Shallow	Mid	Deep	Shallow	Mid	Deep	Shallow	Mid	Deep	
Chromis agilis			155			200		5			320	190		115	220		9	50			160	50	54	242		142	455	2367
Chromis vanderbilti	299	32	160	46	60		84	40	167	10			20			35	177	35	20	145	30	85	34	20	160			1659
Zebrasoma flavescens	6	34		5	2	21	19	13		16	32	28	25	41	19	21	30	48	27	10	10	7	5	4	15	30	32	500
Ctenochaetus strigosus		19	19	20	10	31	7	10		3	43	14	13	18	10		16	21	19	6	5	19	33	10	2	34	34	416
Acanthurus nigrofuscus	17	11		42	27	5	23	24	1	15	5	3	14			22	11	17	14	17	9	20	2	9	44	14	13	379
Acanthurus thompsoni		2	20			20						25						4			140			3		20	124	358
Thalassoma duperrey	16	7	5	15	2	2	6	6	5	8	1	1	7	2	1		18	3	13	16	3	10	4	4	9	3	3	170
Paracirrhites arcatus	16	17		2	2	3		6	6	1				1	1	9	10	1	12	14	4	8	5	4	13	9	5	149
Abudefduf abdominalis		4		12												45			3				37					101
Chromis hanui			4			14		2			14	6		5	5			4			5		3	12		2		76
Myripristis berndti												15		2	5			15					31	3			2	73
Pseudocheilinus evanidus			27		3	3			10		2	5		1	6						2			7		2	1	69
Chaetodon multicinctus	3	6		2		5	3	2			2	4	3	2	3		2	4	3	4			2	3		4	7	64
Scarus sp.juvenile	30	5														15	7			4		2						63
Naso lituratus	2	4	4	2	1	2	1	1	1	2			2			6	3	6	6	8	2	2			3	2	1	61
Acanthurus olivaceus	1	1			2		15	1	6	3			19			1	1			2		2		1	2			57
Scarus sordidus	5	4	4	2								1	1	7				6		4	2	6		2		5	6	55
Halichoeres ornatissimus	4	3		5	1	1	4	3	4	1	3		3	1			5	1	3	1	2	5			1	1		52
Chaetodon kleini			45																								2	47
Gomphosus varius	5			3	2					1	4		2	7	5	1	1	2		2	2	3	2		1	1	1	45
Acanthurus leucoparieus				1												40									1			42
Ctenochaetus hawaiiensis			1			3					1	3			1	5		8			3		2	1	2		8	38
Mulloides flavolineatus																							35					35
Mulloides vanicolensis														35														35
Stegastes fasciolatus		5		7			4				7		2	1					2		1	5						34
Pseudocheilinus octotaenia			2			3		3			2			3	1			5			4	1		3			6	33
Plectroglyphidodon johnstonianus		1		1		4		2		1	4	2		4	6								1	2		1	1	30
Acanthurus blochii	25															4												29
Coris gaimard	2		2	5	2			1			1				1	2	1				1	3		3	1	1	2	28
Forcipiger flavissimus				1		1						4	1		1	1		3	2		1		1	5		6		27
Cephalopholis argus			2	1	1	3	2	1	1		3	3			1			3				1			1		1	24
Canthigaster jactator	3	1						1		1			2				4		3		2	2	3		2			24
Centropyge potteri			2			2						1		3	3			1			1		3	2		1	3	22
Acanthurus nigroris			6	2									5	2		7									1			23
Sufflamen bursa	1	2	2					1	2					1			1		3	1	1	2		1	2		2	22
Pseudocheilinus tetrataenia	3	1	1	2	1	2	1	1			1			1	4							1				1		20
Chromis verater																	2			5	3		2			6		18
Parupeneus multifasciatus	1	1	2	1		1									1		1	3					1			2		14
Zanclus cornutus			1							2								1	3		1			2		1	3	14
Chaetodon quadrimaculatus							2				2							4				1	1			2		12
Parupeneus bifasciatus	1		1	1			2									4				1							1	11
Naso hexacanthus																		5		6								11
Melichthys vidua			2		2				5			1					1											11
Monotaxis grandoculis	1															9												10
Chaetodon ornatissimus	1				2	1	1				1			2						1			1					10
Chromis ovalis																10												10
Xanthichthys auromarginatus			1											1	4						2						1	9
Kyphosus bigibbus																8												8
Dascyllus albisella												7															1	8
Labroides phthirophagus														3				4					1					8
Stenojulis balteata		1	3								1										1	2						8
Acanthurus triostegus										8																		8
Gymnothorax meleagris						1								1			1						1					4
Paracirrhites fosteri	2																1			1								4

Appendix D.2.. Abundance of fish observed along 25 m transects at sites between Wawahiwaa Point and Kaiwi Point on April 4 - 13, 2006. Transect locations are shown in Figure 11. Species ordered by taxonomic order.

Family	Species	Site A			Site B			Site C			Site D			Site E			Site F			Site G			Site H			Site I			TOTAL
		Shallow	Mid	Deep	Shallow	Mid	Deep	Shallow	Mid	Deep	Shallow	Mid	Deep	Shallow	Mid	Deep	Shallow	Mid	Deep	Shallow	Mid	Deep	Shallow	Mid	Deep	Shallow	Mid	Deep	
Labridae	*Labroides phthirophagus*														3				4					1					8
	Stenojulis balteata		1	3								1										1	2						8
	Oxycheilinus unifasciatus												2		1										1				4
	Pseudojuloides cerasinus									3															1				4
	Macropharyngodon geoffroy					1																	1		1				3
	Anampses cuvier																						1						1
	Anampses chrysocephalus																								1				1
Scaridae	*Scarus sp.juvenile*	30	5														15	7			4		2						63
	Scarus sordidus	5	4	4	2								1	1	7				6		4	2	6		2		5	6	55
	Scarus psittacus			1										1									1			1			4
	Scarus rubroviolaceus																									2			2
	Calotomus zonarchus																			1									1
Blennidae	*Cirripectes vanderbilti*														1												1		2
	Plagiotremus goslinei				1												1												2
	Exallias brevis																										1		1
Zanclidae	*Zanclus cornutus*			1							2								1	3		1			2		1	3	14
Acanthuridae	*Zebrasoma flavescens*	6	34		5	2	21	19	13		16	32	28	25	41	19	21	30	48	27	10	10	7	5	4	15	30	32	500
	Ctenochaetus strigosus		19	19	20	10	31	7	10		3	43	14	13	18	10		16	21	19	6	5	19	33	10	2	34	34	416
	Acanthurus nigrofuscus	17	11		42	27	5	23	24	1	15	5	3	14			22	11	17	14	17	9	20	2	9	44	14	13	379
	Acanthurus thompsoni		2	20			20						25						4			140			3		20	124	358
	Naso lituratus	2	4	4	2	1	2	1	1	1	2			2			6	3	6	6	8	2	2			3	2	1	61
	Acanthurus olivaceus	1	1			2		15	1	6	3			19			1	1			2		2		1	2			57
	Acanthurus leucoparieus				1												40									1			42
	Ctenochaetus hawaiiensis			1			3					1	3			1	5		8			3		2	1	2		8	38
	Acanthurus blochii	25															4												29
	Acanthurus nigroris			6	2									5	2		7									1			23
	Naso hexacanthus																		5		6								11
	Acanthurus triostegus										8																		8
	Acanthurus dussumieri									1							3												4
	Acanthurus achilles													1										1			1		3
	Acanthurus guttatus																1												1
	Acanthurus xanthopterus																				1								1
Balistidae	*Sufflamen bursa*	1	2	2					1	2					1			1		3	1	1	2		1	2		2	22
	Melichthys vidua			2		2				5			1					1											11
	Xanthichthys auromarginatus			1											1	4						2						1	9
	Melichthys niger					1														1	1								3
	Sufflamen fraenatus									1																			1
Monacanthidae	*Cantherhines dumerilii*		1													1													2
	Alutera scriptus																									1			1
	Pervagor aspricaudus																					1							1
Ostraciidae	*Ostracion memeagris*				1				1								1												3
Tetraodontidae	*Canthigaster jactator*	3	1						1		1			2				4		3		2	2	3		2			24
	Arothron meleagris						1																						1
Diodontidae	*Diodon histrix*			1																									1

Appendix D.2.. Abundance of fish observed along 25 m transects at sites between Wawahiwaa Point and Kaiwi Point on April 4 - 13, 2006. Transect locations are shown in Figure 11. Species ordered by taxonomic order.

Family	Species	Site A			Site B			Site C			Site D			Site E			Site F			Site G			Site H			Site I			TOTAL
		Shallow	Mid	Deep	Shallow	Mid	Deep	Shallow	Mid	Deep	Shallow	Mid	Deep	Shallow	Mid	Deep	Shallow	Mid	Deep	Shallow	Mid	Deep	Shallow	Mid	Deep	Shallow	Mid	Deep	
Muraenidae	*Gymnothorax meleagris*						1								1			1						1					4
	Gymnothorax undulatus								1																				1
Holocentridae	*Myripristis berndti*												15		2	5			15					31	3			2	73
	Sargocentron ensiferum															1													1
Aulostomidae	*Aulostomus chinensis*												1											1					2
Fistularidae	*Fistularia commersonii*															1													1
Serranidae	*Cephalopholis argus*			2	1	1	3	2	1	1		3	3			1			3				1			1		1	24
Cirrhitidae	*Paracirrhites arcatus*	16	17		2	2	3		6	6	1				1	1	9	10	1	12	14	4	8	5	4	13	9	5	149
	Paracirrhites fosteri	2																1			1								4
	Cirrhitops fasciatus							1																					1
Apogonidae	*Apogon kallopterus*						3																						3
Carangidae	*Caranx melampygus*																		1										1
Lutjanidae	*Alphareus furca*																1				1			1					3
	Lutjanus kasmira		1																										1
Lethirinidae	*Monotaxis grandoculis*	1															9												10
Mullidae	*Mulloides flavolineatus*																							35					35
	Mulloides vanicolensis														35														35
	Parupeneus multifasciatus	1	1	2	1		1									1		1	3					1			2		14
	Parupeneus bifasciatus	1		1	1			2									4				1							1	11
	Parupeneus cyclostomus							2		1																			3
	Parupeneus pleurostigma									1																		2	3
Kyphosidae	*Kyphosus bigibbus*																8												8
Chaetodontidae	*Chaetodon multicinctus*	3	6		2		5	3	2			2	4	3	2	3		2	4	3	4			2	3		4	7	64
	Chaetodon kleini			45																								2	47
	Forcipiger flavissimus				1		1						4	1		1	1		3	2		1		1	5		6		27
	Chaetodon quadrimaculatus							2				2							4				1	1			2		12
	Chaetodon ornatissimus	1				2	1	1				1			2						1			1					10
	Chaetodon auriga			1							2																		3
	Chaetodon lineolatus			2							1																		3
	Chaetodon lunula										2									1									3
	Forcipiger longirostris																			3									3
	Hemiaurichthys thompsoni																										3		3
Pomacanthidae	*Centropyge potteri*			2			2						1		3	3			1			1		3	2		1	3	22
	Centropyge loricula																							1					1
Pomacentridae	*Chromis agilis*			155			200		5			320	190		115	220		9	50			160	50	54	242		142	455	2367
	Chromis vanderbilti	299	32	160	46	60		84	40	167	10			20			35	177	35	20	145	30	85	34	20	160			1659
	Abudefduf abdominalis		4		12												45			3				37					101
	Chromis hanui			4			14		2			14	6		5	5			4			5		3	12		2		76
	Stegastes fasciolatus		5		7			4				7		2	1					2		1	5						34
	Plectroglyphidodon johnstonianus		1		1		4		2		1	4	2		4	6								1	2		1	1	30
	Chromis verater																	2			5	3		2			6		18
	Chromis ovalis																10												10
	Dascyllus albisella												7															1	8
	Plectroglyphidodon imparipenis	1			1				1		1																		4
Labridae	*Thalassoma duperrey*	16	7	5	15	2	2	6	6	5	8	1	1	7	2	1		18	3	13	16	3	10	4	4	9	3	3	170
	Pseudocheilinus evanidus			27		3	3			10		2	5		1	6						2			7		2	1	69
	Halichoeres ornatissimus	4	3		5	1	1	4	3	4	1	3		3	1			5	1	3	1	2	5			1	1		52
	Gomphosus varius	5			3	2					1	4		2	7	5	1	1	2		2	2	3	2		1	1	1	45
	Pseudocheilinus octotaenia			2			3		3			2			3	1			5			4	1		3			6	33
	Coris gaimard	2		2	5	2			1			1				1	2	1				1	3		3	1	1	2	28
	Pseudocheilinus tetrataenia	3	1	1	2	1	2	1	1			1			1	4							1				1		20

Appendix E. Results of photoquadrat surevy of vertical walls at Honokohau Harbor conducted in April 2006. Station locations are shown in Figure 12. Each frame covers an area of 0.6 x 1.0 m. Figures given are percent cover.

Station	Frame	algae	Sponges	*Pocillopora damicornis*	*Pocillopora meandrina*	*Montipora capitata*	*Montipora patula*	*Porites compressa*	*Porites lobata*	*Pavona varians*	*Isognomon californicum*	dead? oyster	Barnacles	*Culcita novaeguineae*	*Diadema paucispinum*	*Echinothrix calamaris*	*Echinometra mathaie*	*Heterocentrotus mammillatus*	*Tripneustes gratilla*	*Holothuria sp.*	Coralline algae	*Gymnothorax flavimarginatus*
3	1	0	0	0	0	0	0	0	0	0	1.5	0	0	0	0	0	0	0	0	0	0	0
	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	4	0	1	0
	3	0	0	0	0	0	0	0	0	0	0	0	8.5	0	0	0	0	0	1	0	0	0
	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0.5	0	0	0
	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	6	0	0	0	0	0	0	0	0	0	0	43.5	9	0	0	0	0	0	1	0	0	0
	7	0	0	0	0	0	0	0	0	0	0	3	1.5	0	0	0	0	0	0	0	0	0
	8	0	0	0	0	0	0	0	0	0	0	0	10.5	0	0	0	0	0	0.5	0	0	0
	9	0	0	0	0	2.5	0	0	0	0	0	0	0	0	0	0	1.5	0	0	0	0	0
	10	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0
	11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.5	0	0	0
4	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.5	0	0	0
	2	0	0	0	0	0	0	0	0	0	0	0	7	0	0	0	0	0	4.5	0	0	0
	3	0	0	0	0	0	0	0	0	0	0	0	11.5	0	0	0	0	0	3	0	0	0
	4	0	0	0	0	0	0	0	0	0	0	0	11	0	0	0.5	0	0	1.5	0	0	0
	5	0	0	0	0	0	0	0	0	0	0	0	6.5	0	0	4	0	0	0	0	0	0
	6	0	0	0	0	0	0	0	0	0	0	0	3.5	0	0	0	0	0	0.5	0	0	0
	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	9	0	0	0	0	0	0	0	0	0	0	0	3.5	0	0	0	0	0	0	0	0	0
	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	1	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0
	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	3	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	4	0	0	0	0	5.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	5	0	0	0	0	0	0	0	0	0	0	0	7	0	0	4	0	0	0	0	0	0
	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	8	0	0.5	0	0	0	0	0	0	0	0	0	0	0	0	2.5	0	0	0	0	0	0
	9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

APPENDIX E

Results of photoquadrat surveys conducted along vertical walls within Honokohau Harbor on April 11, 2006.

Appendix E. Results of photoquadrat surevy of vertical walls at Honokohau Harbor conducted in April 2006. Station locations are shown in Figure 12. Each frame covers an area of 0.6 x 1.0 m. Figures given are percent cover.

Station	Frame	algae	Sponges	*Pocillopora damicornis*	*Pocillopora meandrina*	*Montipora capitata*	*Montipora patula*	*Porites compressa*	*Porites lobata*	*Pavona varians*	*Isognomon californicum*	dead? oyster	Barnacles	*Culcita novaeguineae*	*Diadema paucispinum*	*Echinothrix calamaris*	*Echinometra mathaie*	*Heterocentrotus mammillatus*	*Tripneustes gratilla*	*Holothuria sp.*	Coralline algae	*Gymnothorax flavimarginatus*
9	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	2	0	0	0	0	0	0	0	0	0	0	0	9.5	0	0	2	0	0	0	0	14.5	0
	3	0	0	0	0	0	0	0	0	0	0	27	18	0	0	0	0	0	0.5	0	0	0
	4	0	0	0	0	9	0	0	0	0	0	13.5	0	0	0	1	0	0	0	0	0	0
	5	0	0	0	0	4.5	34	0	0	0	0	0	0	0	0	0.5	0	0	0	0	0	0
	6	0	0	0	0	5.5	0	0	0	0	0	0	0	0	0	0.5	0	0	0	0	0	0
	7	0	0	0	0	13.5	0	0	0	0	0	0	0	0	2.5	1	0	0	0.5	0	0	0
10	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0
	2	0	0	0	0	0	0	0	0	0	0	4.5	7	0	0	1.5	1	0	4.5	0	8	0
	3	0	0	0	0	0	0	0	0	0	0	8.5	11.5	0	0	4	0	0	1.5	0	0	0
	4	0	0	0	0	9.5	0	0	0	0	0	4.5	7	0	0	2.5	0	0	1.5	0	0	0
	5	0	0	0	0	8.5	13	0	0	0	0	6	8.5	0	0	0	0	0	0	0	0	0
	6	0	0	0	0	11	7	0	0	0	0	0	0	0	0	0.5	0	0	0	0	0	0
	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0
	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11	1	98.5	0	0	0	0	0	0	0	0	0	1.5	0	0	0	0	0	0	0	0	0	0
	2	0	0	0	0	0	0	0	0	0	16.5	0	0	0	0	0	0	0	0	0	0.5	0
	3	0	0.5	0	0	0	0	0	0	0	21	0	0	0	0	0.5	0	0	1	0	0	0
	4	0	0	0	0	0	0	0	0	0	8	0	0	0	0	0.5	0	0	0	0	0	0
	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.5	0
12	1	97	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0
	2	0	0	0	0	0	0	0	0	0	7.5	0	4.5	1	0	0	0	0	0	0	0	0
	3	0	0	0	0	0	0	0	0	0	7	0	8.5	0	0	0	0	0	0	0	0	0
	4	0	0	0	0	0	0	0	0	0	0	2.5	3.5	0	0	0	0	0	0	0	0	0
	5	0	0	0	0	0	0	0	0	0	0	0	5	0	0	0	0	0	0	0	0	0
13	1	90	0	0	0	0	0	0	0	0	0	3.5	0	0	0	0	0	0	0	0	0	0
	2	95	0	0	0	0	0	0	0	0	3.5	0	0	0	0	0	0	0	0	0	0	0
	3	0	3.5	0	0	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0	3.5	0
14	1	0	0	0	0	0	0	0	0	0	3.5	7.5	10	0	0	0	0	0	0	0	0	0
	2	98.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.5	0
	3	87.5	0	0	0	0	0	0	0	0	0	1.5	2	0	0	3.5	0	0	0	0	3	0

Appendix E. Results of photoquadrat surevy of vertical walls at Honokohau Harbor conducted in April 2006. Station locations are shown in Figure 12. Each frame covers an area of 0.6 x 1.0 m. Figures given are percent cover.

Station	Frame	algae	Sponges	*Pocillopora damicornis*	*Pocillopora meandrina*	*Montipora capitata*	*Montipora patula*	*Porites compressa*	*Porites lobata*	*Pavona varians*	*Isognomon californicum*	dead? oyster	Barnacles	*Culcita novaeguineae*	*Diadema paucispinum*	*Echinothrix calamaris*	*Echinometra mathaie*	*Heterocentrotus mammillatus*	*Tripneustes gratilla*	*Holothuria sp.*	Coralline algae	*Gymnothorax flavimarginatus*
6	1	0	0	0	0	0	0	0	0	0	3.5	0	0	0	0	0	0	0	0.5	0	0	0
	2	0	0	0	0	0	0	0	0	0	0	0	4.5	0	0	0	0	0	0.5	0	0	0
	3	0	0	0	0	0	0	0	0	0	0	6	3.5	0	0	0.5	0	0	1	0	0	0
	4	0	0.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.5	0	0	0
	6	0	0	0	0	0	0	0	0	0	0	5.5	0	0	0	0	0.5	0	0.5	0	0	0
	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.5	0	0	0
	8	0	0.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7	1	0	0	0	0	0	0	0	0	0	0	0	52	0	0	0	1.5	0	2.5	0	0	0
	2	0	0	0	0	0	0	0	0	0	0	0	15	0	0	2.5	0	0	2.5	0	0	0
	3	0	0	0	0	9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	4	0	2	0	0	0	0	0	1	0	0	0	8	0	0	1.5	0	0	1	0	0	0
	5	0	0	0	0	0	0	0	1	0	0	0	26.5	0	0	1	1	0	1	0	0	0
	6	0	1	0	0	1.5	0	0	0	0	0	0	0	0	0	0.5	0	0	0	0	2	0
	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.5	0	0	0	0	0	0
	8	0	0	0.5	0	0	0	0	1	0	0	0	0	0	0	0.5	0	0	0	0	0	0
	9	0	0	0	0	0	0	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0
	10	32	0	0	0	0	0	0	0.5	0	0	0	0	0	0	2.5	0	0	0	0	0	0
8	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.5	0	0	0
	2	0	0	0	0	0	0	0	0	0	0	0	56	0	0	0	0	0	0	0	4.5	0
	3	0	0	0	0	0	0	0	0	0	0	13	34	0	0	0	0	0	0	0	0	0
	4	0	0	0	0	0	0	0	0	0	0	0	50.5	0	0	0	0	0	0	0	0	0
	5	0	0	0	0	0	0	0	0	0	0	8.5	0	0	0	0	0	0	0	0	0	0
	6	0	0	0	0	0	0	0	0	0	0	0	23	0	0	0	0	0.5	4	0	0	0
	7	0	0	0	0	0	0	0	4.5	0	0	0	0	0	0	0.5	0	0	0.5	0	0	0
	8	0	0	0	0	1	0	0	0.5	0	0	0	0	0	0	0	0	0	0	0	0	0
	9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	10	0	0	0	0	0	0	0	0	0	0	22	0	0	0	0.5	0	0	0.5	0	0	0

Appendix E. Results of photoquadrat surevy of vertical walls at Honokohau Harbor conducted in April 2006. Station locations are shown in Figure 12. Each frame covers an area of 0.6 x 1.0 m. Figures given are percent cover.

Station	Frame	algae	Sponges	*Pocillopora damicornis*	*Pocillopora meandrina*	*Montipora capitata*	*Montipora patula*	*Porites compressa*	*Porites lobata*	*Pavona varians*	*Isognomon californicum*	dead? oyster	Barnacles	*Culcita novaeguineae*	*Diadema paucispinum*	*Echinothrix calamaris*	*Echinometra mathaie*	*Heterocentrotus mammillatus*	*Tripneustes gratilla*	*Holothuria sp.*	Coralline algae	*Gymnothorax flavimarginatus*
25	1	0	0	0	0	0	0	0	0	0	94	0	0	0	0	0	0	0	0	0	0	0
	2	0	0	0	0	0	0	0	0	0	65.5	0	0	0	0	0	0	0	0	0	0	0
	3	0	1.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	4	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	5	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
26	1	0	0	0	0	0	0	0	0	0	57.5	0	0	0	0	0	0	0	0	0	0	0
	2	9	3	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0
	3	7.5	1.5	0	0	0	0	0	0	0	0	2.5	0	0	0	0	0	0	0	0	0	0
	4	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
27	1	0	0	0	0	0	0	0	0	0	19.5	3.5	7	0	0	0	0	0	0	0	0	0
	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
28	1	0	0	0	0	0	0	0	0	0	89.5	0	0	0	0	0	0	0	0	0	0	0
	2	4.5	1.5	0	0	0	0	0	0	0	13.5	0	8.5	0	0	0	0	0	0	0	0	0
	3	48	1.5	0	0	0	0	0	0	0	0	0	6.5	0	0	0	0	0	0	0	0	0
	4	0	3.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	5	0	3.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
29	1	0	0	0	0	0	0	0	0	0	38	11	0	0	0	0	0	0	1	0	0	0
	2	0	1	0	0	0	0	0	0	0	21.5	12	4	0	0	0	0	0	0	0	0	0
	3	4.5	3	0	0	0	0	0	0	0	0	0	16.5	0	0	0	0	0	0	0	0	0
	4	0	3.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	5	0	2.5	0	0	0	0	0	0	0	0	0	3.5	0	0	3	0	0	0	0	0	0
30	1	0	0	0	0	0	0	0	0	0	47	0	0	0	0	0	0	0	0	0	0	0
	2	0	0	0	0	0	0	0	0	0	14	0	2	0	0	3	0	0	4	0	0	0
	3	0	0	0	0	0	0	0	0	0	5	4	9	0	0	3	0	0	0	0	0	0
	4	78	1.5	0	0	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0
	5	0	1	0	0	0	0	0	0	0	0	2	31	0	0	0	0	0	0	0	0	0

Appendix E. Results of photoquadrat surevy of vertical walls at Honokohau Harbor conducted in April 2006. Station locations are shown in Figure 12. Each frame covers an area of 0.6 x 1.0 m. Figures given are percent cover.

Station	Frame	algae	Sponges	*Pocillopora damicornis*	*Pocillopora meandrina*	*Montipora capitata*	*Montipora patula*	*Porites compressa*	*Porites lobata*	*Pavona varians*	*Isognomon californicum*	dead? oyster	Barnacles	*Culcita novaeguineae*	*Diadema paucispinum*	*Echinothrix calamaris*	*Echinometra mathaie*	*Heterocentrotus mammillatus*	*Tripneustes gratilla*	*Holothuria sp.*	Coralline algae	*Gymnothorax flavimarginatus*
15	1	0	0	0	0	0	0	0	0	0	42.5	7	0	0	0	0	0	0	0	0	0	0
	2	6	0	0	0	0	0	0	0	0	0	4.5	4	0	0	0	0	0	0	0	1.5	0
	3	75	2.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.5	0
	4	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
16	1	0	0	0	0	0	0	0	0	0	90	0	0	0	0	0	0	0	0	0	0	0
	2	0	0	0	0	0	0	0	0	0	17.5	0	0	0	0	0	0	0	0	0	0	0
	3	90	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3.5	0
	4	99	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	5	0	1	0	0	0	#####	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
17	1	0	0	0.5	0	0	0	0	0	0	53.5	0	0	0	0	0	0	0	0	0	0	0
	2	0	0.5	0	0	0	0	0	0	0	13.5	0	0	0	0	0	0	0	0	0	1	0
	3	0	1.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6	0
	4	0	2.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2.5	0
18	1	0	0	0	0	0	0	0	0	0	48.5	0	0	0	0	0	0	0	0	0	0	0
	2	0	0	0	0	5	0	0	0	0	38.5	0	0	0	0	0	0	0	0	0	0	0
	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
19	1	13	0	0	0	0	0	0	0	0	85	0	0	0	0	0	0	0	0	0	0	0
	2	0	0	0	0	0	0	0	0	0	28.5	0	0	0	0	0	0	0	0	0	0	0
20	1	0	0	0	0	0	0	0	0	0	58	0	0	0	0	0	0	0	0	0	0	0
	2	0	0	0	0	0	0	0	0	0	23.5	0	0	0	0	0	0	0	0	0	0	0
21	1	0	0	0	0	0	0	0	0	0	71	0	0	0	0	0	0	0	0	0	0	0
	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22	1	0	0	0	0	0	0	0	0	0	67.5	0	0	0	0	0	0	0	0	0	0	0
	2	0	0	0	0	2	0	0	0	0	13	0	32.5	0	0	0	0	0	0	0	0	0
23	1	0	0	0	0	0	0	0	0	0	85	0	0	0	0	0	0	0	0	0	0	0
	2	0	0	0	0	0	0	0	0	0	29	0	0	0	0	0	0	0	0	0	0	0
24	1	0	0	0	0	0	0	0	0	0	84	0	0	0	0	0	0	0	0	0	0	0
	2	0	0	0	0	0	0	0	6.5	0	23.5	0	0	0	0	0	0	0	0	0	0	0
	3	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	4	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Appendix E. Results of photoquadrat surevy of vertical walls at Honokohau Harbor conducted in April 2006. Station locations are shown in Figure 12. Each frame covers an area of 0.6 x 1.0 m. Figures given are percent cover.

Station	Frame	algae	Sponges	*Pocillopora damicornis*	*Pocillopora meandrina*	*Montipora capitata*	*Montipora patula*	*Porites compressa*	*Porites lobata*	*Pavona varians*	*Isognomon californicum*	dead? oyster	Barnacles	*Culcita novaeguineae*	*Diadema paucispinum*	*Echinothrix calamaris*	*Echinometra mathaie*	*Heterocentrotus mammillatus*	*Tripneustes gratilla*	*Holothuria sp.*	Coralline algae	*Gymnothorax flavimarginatus*
36	1	0	0	0	0	0	0	0	0	0	10.5	0	0	0	0	0	0	0	0	0	0	0
	2	0	0	0	0	0	0	0	0	0	20.5	0	0	0	0	0	0	0.5	1	0	4	0
	3	0	0	0	0	0	0	0	0	0	0	10.5	3.5	0	0	0	0	0	0	0	4.5	1
	4	0	0	0	0	0	0	0	3	0	0	0	0	0	0	1	0	0	1	0	0	0
	5	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	1.5	0	0	0
	6	0	0	0	0	6.5	0	1	3	0	0	0	0	0	0	0	0	0	0	0	0	0
	7	0	0	0	0	0	0	0	1.5	0	0	0	0	0	0	0	0	0	0	0	0	0
	8	0	0	0	0	0	0	0	3.5	0	0	0	0	0	0	0.5	0	0	0	0	0	0
37	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	1.5	0	0	9	0
	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0	2	4	0	7	0
	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.5	0	3.5	8.5	0	0	0
	4	0	0	0	0	0	0	0	0	0	0	0	23.5	0	0	1	0.5	2	6.5	0	0	0
	5	0	0	0	0	0	0	0	0.5	0	0	0	0	0	0	1	0.5	0	4	0	0	0
	6	0	0	0	0	0	0	4.5	0	0	0	0	0	0	0	1.5	0	0	2	0	0	0
38	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.5	0.5	0.5	4	0	6	0
	2	0	0	0	2	0	0	0	0	0	0	0	0	0	0	1	0	0.5	7.5	0	7	0
	3	0	0	0	0	0	0	0	0	0	0	0	26.5	0	0	0	0	0	4	0	8.5	0
	4	0	0	0	0	0	0	0	0	0	0	0	50	0	0	0	0	0	3	0	7.5	0
	5	0	0	0	0	0	5	0	0	0	0	0	0	0	0	1	0	0.5	2	0	0	0
	6	0	0	0	0	0	9	0	0	0	0	0	0	0	0	1.5	0.5	0	1	0	0	0
	7	0	0	0	0	0	6.5	0	0	0	0	0	0	0	0	1.5	0	0.5	0	0	0	0
39	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.5	1.5	0	2	0
	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3.5	1	1	2	0	12	0
	3	22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2.5	0	0	0
	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.5	0	2.5	8	0	0	0
	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.5	0	2	8.5	0	0	0
	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	10	0	8.5	0
	7	0	0	0	0	0	0	0	0	0	0	0	6.5	0	0	0	0	0	6	0	7	0
	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7	0	0	0

Appendix E. Results of photoquadrat surevy of vertical walls at Honokohau Harbor conducted in April 2006. Station locations are shown in Figure 12. Each frame covers an area of 0.6 x 1.0 m. Figures given are percent cover.

Station	Frame	algae	Sponges	*Pocillopora damicornis*	*Pocillopora meandrina*	*Montipora capitata*	*Montipora patula*	*Porites compressa*	*Porites lobata*	*Pavona varians*	*Isognomon californicum*	dead? oyster	Barnacles	*Culcita novaeguineae*	*Diadema paucispinum*	*Echinothrix calamaris*	*Echinometra mathaie*	*Heterocentrotus mammillatus*	*Tripneustes gratilla*	*Holothuria sp.*	Coralline algae	*Gymnothorax flavimarginatus*
31	1	0	0	0	0	0	0	0	0	0	23.5	29.5	0	0	0	0	0	0	0	0	0	0
	2	0	0	0	0	0	0	0	0	0	0	37	0	0	0	0	0	0	0	0	0	0
	3	0	1.5	0	0	0	6.5	0	0	0	2	0	13.5	0	0	0	0	0	0	0	0	0
	4	0	3	0	0	0	10.5	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0
	5	0	1	0	0	0	0	0	0	0	0	0	4.5	0	0	0	0	0	0	0	0	0
32	1	0	0	0	0	0	0	0	0	0	53.5	15.5	0	0	0	0	0	0	0	0	0	0
	2	0	4	0	0	0	0	0	0	0	26	4.5	5.5	0	0	0	0	0	0	0	0	0
	3	0	3.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.5	0	0	0	0	0	0
33	1	0	0	0	0	0	0	0	0	0	28	0	0	0	0	0	0	0	0	0	0	0
	2	0	0	0	0	0	0	0	0	0	3	3	69	0	0	0	0	0	0	0	0	0
	3	0	5.5	0	0	0	0	0	0	0	0	8	82.5	0	0	0	0	0	0	0	0	0
	4	0	0	0	0	0	0	0	0	0	0	17	14	0	0	3.5	0	0.5	0	0	0	0
	5	0	3.5	0	0	0	0	0	0	0	0	0	5.5	0	0	1.5	0	0	0	0	0	0
34	1	0	0	0	0	0	0	0	0	0	16.5	0	0	0	0	0	0	0	0	0	0	0
	2	0	0	0	0	0	0	0	0	0	34.5	0	4.5	0	0	1.5	0	0	0	0	4.5	0
	3	0	0	0	0	3.5	0	0	0	0	16.5	0	0	0	0	0.5	0	0	0	0	12	0
	4	0	0	0	0	0	0	0	0	0	0	21	0	0	0	1.5	0	0	0	0	0	0
	5	0	1.5	0	0	0.5	0	0	0	0	0	0	0	0	0	1.5	0	0	0	0	0	0
35	1	0	0	0	0	0	0	0	0	0	15.5	0	0	0	0	0	0	0	0	0	0	0
	2	0	0	0	0	0	0	0	0	0	5.5	25.5	0	0	0	1	0	0	2	0	0	0
	3	0	0	0	0	0	0	0	0	0	0	9	0	0	0	2	0	0	0	0	2.5	0
	4	0	0	0	0	0	0	0	1.5	0	0	23	8.5	0	0	2	0	0	0	0	0	0
	5	0	0	0	0	0	0	0	0	0	0	2.5	5	0	0	2	0	0	0	0	0	0
	6	0	0	0	0	1	0	0	0.5	0	0	0	0	0	0	1.5	0	0	0	1	0	0
	7	0	0	0	0	0	0	0	0	0	0	0	7	0	0	1	0	0	0	0	0	0

Appendix E. Results of photoquadrat surevy of vertical walls at Honokohau Harbor conducted in April 2006. Station locations are shown in Figure 12. Each frame covers an area of 0.6 x 1.0 m. Figures given are percent cover.

Station	Frame	algae	Sponges	*Pocillopora damicornis*	*Pocillopora meandrina*	*Montipora capitata*	*Montipora patula*	*Porites compressa*	*Porites lobata*	*Pavona varians*	*Isognomon californicum*	dead? oyster	Barnacles	*Culcita novaeguineae*	*Diadema paucispinum*	*Echinothrix calamaris*	*Echinometra mathaei*	*Heterocentrotus mammillatus*	*Tripneustes gratilla*	*Holothuria sp.*	Coralline algae	*Gymnothorax flavimarginatus*
40	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	1.5	0	0
	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	9	0	9.5	0
	3	0	0	0	0	0	0	0	0	0	0	0	13.5	0	0	0	0	0	3	0	11.5	0
	4	0	0	0	0	0	0	0	0	0	0	0	29.5	0	0	0	0	0	3.5	0	41	0
	5	0	0	0	0	0	0	0	0	0	0	0	14	0	0	0	0	0	5	0	18	0
	6	0	0	0	0	0	0	0	0	0	0	0	20.5	0	0	0	0	0	1	0	11	0
	7	0	0	0	0	3	0	0	0	0	0	0	11.5	0	0	0	0	0	0	0	0	0
41	1	90.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.5	0	4.5	0
	2	0	0	0	6	0	0	0	0	0	0	0	0	0	0	0	0	0.5	1	2	0	0
	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.5	1.5	2	1.5	3.5	0
	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.5	7.5	0	4.5	0
	5	0	0	0	0	0	0	0	0	0	0	0	16.5	0	0	1	0	0	4.5	0	2.5	0
	6	0	0	0	0	0	0	0	6	0	0	0	38.5	0	0	0	0	0	0	0	9.5	0
	7	0	0	0	0	0	0	0	23	0	0	0	0	0	0	0	1.5	0.5	1.5	0	0	0
	8	0	0	0	0	0	5	0	29.5	0	0	0	0	0	0	0	0	0	1	0	0	0
	9	0	0	0	0	4	0	0	22.5	0	0	0	0	0	0	0.5	0	0	2	0	0	0
	10	0	0	0	0.5	0	0	0	0	0	0	0	0	0	0	0	0	0	1.5	0	0	0
	11	0	0	0	0.5	0	0	0	1.5	0	0	0	0	0	0	0	0	0	2	0	0	0
	12	0	0	0	0.5	0	0	0	71	0	0	0	0	0	0	0	1	0	0	0	0	0

Appendix H-2

An Inventory and Assessment of Anchialine Pools Including Management and Mitigation Recommendations

By David K. Chai,
Aquatic Resources
Management and Design

An Inventory And Assessment Of Anchialine Pools Including Management And Mitigation Recommendations For The Kona Kai Ola Project, Kealakehe, Hawaii

Prepared for:

Oceanit Laboratories, Inc.

Prepared by:

David K. Chai
Aquatic Resources Management And Design
Kamuela, Hawaii

June 14, 2007

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Introduction

Jacoby Development, Inc. is proposing to develop approximately 530 acres of land in lower Kealakehe, North Kona, on the Island of Hawaii. The development will consist of mixed urban, resort, and commercial facilities. Included in the plan will be an 800 slip marina and associated boating facilities, a seawater lagoon, and open space. One area planned for protected open space contains a number of anchialine pools, archaeological sites and an estuarine habitat.

1.0 Study Background and Purpose

In 1973 L.B. Holthuis originated the term anchialine pool which citation protocol dictates to be the proper term. Two anchialine pool surveys were conducted at Kealakehe to determine the existing water quality and biological conditions, probable impacts, and mitigation measures necessary to minimize potential adverse effects. The first survey was conducted in April of 2006, and included a biological survey and detailed nutrient analysis of anchialine waters. That survey, included pools located both north and south of Honokohau harbor. The second survey was conducted in May 2007, and focused on intensive diurnal and nocturnal biological surveys and limited water quality analysis of the southern group of anchialine pools exclusively. This southern group in the vicinity of Alula cove was selected for a second survey, as they are more likely to be impacted by the proposed Kona Kai Ola development project. The information and recommendations presented herein are drawn from both surveys as well as published literature on anchialine system and their management, consultation with others involved with anchialine pool research and management, and 17 years of applied anchialine pool and wetland management by this author.

This study was contracted by Oceanit Laboratories, Inc. to conduct intensive field surveys incorporating 2 diurnal and 2 nocturnal samplings during higher high tide periods. The survey will provide a current assessment of the contents and state of anchialine pools in the project area. Of particular concern is the potential for adverse ecological effects on anchialine resources due to the proposed harbor expansion and from construction activities and operations. Consequently, this paper will examine other anchialine systems that contain similar attributes, which have faced similar development situations. Based on an aggregate of existing data and information, this document will address possible management and mitigation measures.

2.0 Anchialine Pools as an Ecological Resource

2.1 Background

Anchialine pools are isolated coastal exposures of the groundwater table occupying depressions in historic or recent prehistoric lava flows and porous limestone depressions. These pools contain mixohaline water, and although lacking surface connection to the sea, their water levels exhibit damped tidal fluctuation indicating a subsurface connection to the ocean. Since these pools exist in low lying coastal depressions, in some cases shallow pools may disappear during low tide, which restricts the colonization of certain organisms. Conversely, some pools that were apparently isolated at low tide coalesce during high tide, forming larger singular pools, and are considered pool complexes with homogeneous biological and water chemistry characteristics. Many of the sampled pools at Kealakehe fall into these two categories. Anchialine pools are rare among aquatic ecosystems and geographically limited in the United States to Hawaii. It is estimated that nearly 700 pools exist in Hawaii, most of which occur along the west coast of Hawaii Island between Kawaihae and Kailua-Kona. The ecological significance of Hawaii's anchialine pools owes primarily to their role as habitat for a variety of unique flora and fauna. Their biota is distinctive in community structure and species endemism. Two classes of organisms are found in anchialine pools, epigeal and hypogeal species. The former require illuminated water and are often common to other coastal aquatic habitats, while hypogeal species spend a substantial portion of their life in the dark, which in anchialine systems corresponds to the subterranean interstices within the groundwater table.

2.2 Threats to Anchialine Resources

Anchialine pool ecosystems in West Hawaii are under increasing threat of degradation due to a number of factors. The single greatest threat is the introduction and spread of alien fish and plant species. A lesser threat is groundwater contamination. The effects of alien fish in anchialine pools is rapid senescence, both directly due to predation and competition, and indirectly through a change in the pools trophic ecology, predominantly due to the loss of primary consumers and detritivores. Combined, these changes accelerate eutrophication, sedimentation, infilling, and ultimately the demise of the pool. This altered condition is exacerbated when groundwater contamination in the form of chronic high nutrient levels is present and flushing rates are reduced, promoting rapid filamentous chrysophyte and chlorophyte production. In addition, elevated nutrients promote higher growth rates of terrestrial and riparian vegetation. Large or dense vegetation around pools add leaf litter and increase root mass within groundwater interstices around pools, which decrease water exchange, adding to the senescence process.

In anchialine systems that contain intact native biota, adequate flushing, and physically maintained riparian vegetation, elevated nutrient levels have little or no observable effect on the stability of the system. Anchialine systems are typically high in dissolved nutrients (relative to the ocean) from natural and anthropogenic sources, and inorganic nutrients in

anchialine pools vary among locations and may be as high or low in developed coastal areas as in pristine undeveloped areas. (Brock and Norris, 1988, Brock and Kam, 1997). Pools with native aquatic fauna dominated by *Halocaridina rubra*, a small red caridean shrimp most often associated with anchialine pools, usually have a compliment of lower order crustacea, mollusks, and microfauna. Most substrates in the sunlit pools are blanketed with cyanophytic crusts or epilithon, and interspersed with low-cropped filamentous chlorophytes. It is this complete diverse and rich ecology that prevents filamentous and matted algae from dominating and overwhelming a system. Consequently, healthy anchialine ecosystems in developed and undeveloped coastal areas remain intact even when faced with elevated dissolved nutrient concentrations from natural or anthropogenic sources (Brock & Kam, 1997, Chai, personal observation).

2.2.1 Salinity Levels and Effects in Anchialine Systems

In a 1974 study by Maciolek and Brock, 298 pools along the leeward coast of Hawaii Island were inventoried, and contained salinities of less than 15ppt for 93% of them. They ranged from 1ppt -30 ppt, with the average being 7ppt. Variations in salinity were seldom less than a few parts per thousand (Maciolek and Brock, 1974). However, salinity along the vertical gradient exhibits much more variation among locations along the West Hawaii coastline. For example, within the ahupua'a of Kawaihae, a salinity of 25ppt is reached at an average depth of approximately 18 meters below sea level within 100 meter of the shoreline. At Ka'upulehu, within the same distance of the shore a salinity of 25ppt is reached at approximately 6.8 meters, and Opaeula are drawn from wells over 18 meters below sea level with salinities averaging 31 ppt. Of the hundreds of anchialine pools observed and documented by this author and other anchialine pool researchers, *H. rubra* and *Metabetaeus lohena* are seldom observed in pools with salinities higher than 25 parts per thousand (ppt). These high salinity pools typically have a high level of connectivity to the ocean, and this connection often allows a variety of predatory and competitive marine and euryhaline fish and crustacea to access these anchialine pools and deplete or eliminate hypogeal shrimp.

At Hualalai Resort in Ka'upulehu, North Kona, Hawaii, moderate to high salinity fluctuation in anchialine pools has exhibited no apparent adverse changes to the anchialine ecology, even when facing salinity changes of up to 23 ppt. Two large man-made anchialine pools (1.4 million and 65,000 gallons) and a natural pool enlarged from 1,000 gallons to 40,000 gallons, were created in 1993 and all were surcharged in 1995 with high salinity well water to 27ppt in an attempt to stop the growth of a filamentous algae, *Melosira sp.* and *Cladophora sp.* These two types of algae are pioneer species in newly created or dramatically disturbed anchialine pools that lack the benefit of an adjacent healthy anchialine ecosystem to seed them. The strategy worked to eliminate filamentous algae, and during the first four years, the largest pond contained tens or hundreds of millions of *H. rubra* and millions of *M. lohena* that were especially abundant at night. The decline of these populations was gradual as marine fish were introduced to the pool, and eventually the hypogeal shrimp were observed only at night. The 65,000 gallon man-made anchialine pool located approximately 200 meters away was also surcharged to 27ppt for approximately 1 year until a stable anchialine ecosystem was developed, allowing the surcharge system to be turned off. The pool reverted back to 6ppt and the ecosystem remained intact with dense populations of many anchialine organisms. In subsequent years, the pool was surcharged for a few weeks during the spring and fall to clarify the water during *Enteromorpha* sp. sporulation, with no apparent adverse effects. The enlarged natural pond (40,000 gal.) contained a salinity of 2-4ppt, and supported indigenous widgeon grass (*Ruppia maritime*) and an extremely dense population of *H. rubra* and *M. lohena*. It was surcharged on a periodic basis to 20ppt to eliminate alien Dragonfly larvae and Bufo tadpoles, the presence of which result in the decline and disappearance of hypogeal shrimp. This dense and stable community of native species in both pools existed for 11years until Minnows (*Poecilia sp.* and *Gambusia sp.)* were introduced to the pools in 2005, which devastated their ecology within 6 months. The anchialine pools that were untouched or enlarged, containing an intact native ecology, have remained intact since prior to the construction of the Resort.

2.2.2 Dissolved Nutrients in Anchialine Systems

Various scientists have measured groundwater nutrient concentrations from undeveloped sites in West Hawaii, over time. Brock has reported that nitrate nitrogen in these pools ranged from 280ug/l to 2800ug/l and orthophosphate ranged from 6.2ug/l to 201ug/l (Brock and Kam 1997). Kealakehe pools fall in the higher range in regard to dissolved nitrate nitrogen, having values between 1664ug/l to 2960ug/l with an average 2027ug/l. Orthophosphate ranged from 14ug/l to 32ug/l, averaging 21.6ug/l (Ziemann, 2006), which fell in the lower range compared to other undeveloped sites. Nutrient levels in man-made, modified, and natural pools at Ka'upulehu (a developed area) were recorded between 1989 prior to construction in 1994, and through to 2000. The pools contained nitrate nitrogen levels averaging 2106ug/l prior to construction and 2749ug/l during and after construction. Orthophosphate level prior to construction, averaged 154.4ug/l, while during and after construction orthophosphate levels averaged 149.7ug/l. The highest concentrations of nutrients in the pools occurred during the grow-in period of the landscape and following high rain events. Similar to the findings of Brock at Waikoloa, no apparent adverse effects were observed in healthy anchialine pools. However, disturbed or newly created pools began the process of eutrophication with heavy growths of *Cladophora sp.* until they were cleaned of all sediment and algae, surcharged with high salinity well water, and manually seeded from healthy pools and naturally recolonized with native biota.

There has been a great deal of research conducted since the 1980's by Brock on anchialine pools at Waikoloa and around the State. A good summary assessment on the effects of alien species, high nutrient concentrations, and other types of groundwater contamination on anchialine pools, can be found in Brock and Kams 1997 study entitled "Biological and Water Quality Characteristics of Anchialine Resources in Kaloko-Honokohau National Historical Park" (Brock and Kam, 1997). This study also examines a number of Management recommendations for the Parks pools that may apply to the anchialine resources at Kealakehe.

3.0 Anchialine Pools as Cultural Resource

In addition to their ecological value, anchialine pools are of significant cultural importance. Hawaiians of the past relied on anchialine resources for their livelihood and survival, and maintaining the health of these systems was of high importance. Hawaiian historians, who speak of the anchialine pools within the arid lands of West Hawaii, describe these pools as being a source for drinking and cooking water, bathing, irrigation, and aquaculture. Individual pools typically had a specific use and were well maintained.

Of particular importance were anchialine pools as habitat for Opaeula (*Halocaridina rubra*). Fishermen would gather hundreds of these shrimp into small balls which were sometimes mixed with fine red cinder to add bulk, and they would set out in their canoes to specific areas in the ocean where Opelu (Mackerel Scad, *Decapterus macarellus*) would gather in schools called a Ko'a Opelu. The balls of shrimp would then be released among the Opelu and nets would be set to harvest the fish as they fed upon the shrimp. During the Kapu seasons when Opelu fishing was not allowed, the Ko'a Opelu would continue to be fed and maintained as an early form of open-ocean farming or ranching. (H. Springer, L. Lightner, and C. Torres, pers. comm.) Some fishermen today practice the same fishing technique, and rely on a stable source of Opaeula to catch Opelu. The importance of this fishing tradition cannot be understated. Today, Opelu are not only a highly valued source of food, but they and the fishing methods surrounding them, continue to be a direct link to Hawaiian culture, values, and traditions of the past. The anchialine pools at Kealakehe offer a unique opportunity to help continue this tradition. Further study on the cultural use of anchialine pools of Kealakehe, Honokohau, and Kaloko by early Hawaiian inhabitants should be undertaken and incorporated into the final management plan.

4.0 Findings and Recommendations

The study site was comprised of 19 anchialine pools. Of the 19, six were considered high tide pools (exposed only at medium or high tide), seven were considered pool complexes (individual pools at low tide and interconnected at high tide), and six were single isolated pools. Three of the anchialine pools identified by Ziemann in the 2006 study were considered part of an estuary complex with direct connection to the ocean. Location, physical characteristics, aquatic macrofauna, and floral communities were recorded during higher high tide.

There were several signs of direct human use and disturbance in the pools such as trash receptacles and toilet facility. However, the greatest degradation to the majority of the anchialine and estuarine resources was due to the presence of alien fish, including topminnows and tilapia, and introduced plants, predominantly pickleweed and mangrove.

Figure 1. Location of Anchialine Pools and Estuary at Kealakehe

4.1 Survey Approach and Method

The field survey approach for anchialine pools at Kealakehe was based on recommendations made by John A. Maciolek, one of the pioneers in anchialine pool research (Maciolek, 1987). The survey was conducted on May 20th and 21st, 2007, and all pools were visually inspected each day and night at or near mean higher high tide periods. Since the inventory of aquatic fauna was of primary importance, intensive surveying was necessary during nocturnal high tides, a period conducive to anchialine faunal activity. Estuarine fauna were also recorded both days and nights as part of this study.

Temperature, salinity, oxygen and pH, were measured with an YSI model 556 multi-parameter meter, and were taken in all pools during higher high tide. These four parameters were selected because they are essential limiting factors governing populations of aquatic organisms in the anchialine biotope (Maciolek pers. comm.). All pools were less than 1 meter deep so all measurements were taken at or near the bottom of pools where water quality exhibits the most stability. Specific ions are also important factors to be considered in an aquatic ecosystem but were beyond the scope of this study. A water analysis and monitoring program is addressed later in this paper. Other physical parameters were recorded at higher high tide, and included surface water dimension, average pool depth, type of pond feature (i.e. crack, low lying depression, collapsed lava tube, etc.), and sediment depth and composition. All observed aquatic fauna was recorded and a relative abundance rating attributed to their numbers. Quadrat sampling was not used since both hypogeal shrimp species often occur in groups or clusters in a specific area of the pool. Consequently, a physical quadrant count may not be representative of the entire pool or pool complex for short-term analysis. However, long-term monitoring should involve more quantitative analysis using fixed sampling points. Riparian vegetation was a dominating feature of many Kealakehe pools and was noted in this study. Anchialine pool and estuary sites were recorded on a U.S. Geological Survey topographic map.

4.2 Survey Results

A taxonomic list of aquatic fauna observed is presented in Table 1, and includes their occurrence in each of the 19 pools and a relative abundance rating. Table 2 indicates the individual pools physical, water quality, substrate, and riparian vegetation characteristics.

Table 1. A list of aquatic fauna and their relative abundance in individual pools and pool complexes. A (n) suffix indicates organisms were observed only at night.

Abundance Rating:
1 = Less than 3 individual observed.
2 = several individuals observed or uncommon occurrence relative to other pools
3 = Common occurrence with many individuals observed relative to other pools
4 = Abundant throughout the pool or pool complex and/or numerous individuals occurring in groups.

Pool	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Group/taxon																			
Mollusca																			
Theodoxus																			
cariosus	4		2	2	2				1		2			2	3				4
Melania sp.											2			3	2			3	
Crustacea																			
Halocaridina rubra				3	2n	3	3	3	2n	3	2n	1n	2	3n	1n	2	2n	3	2n
Metabetaeus lohena				2	2n	2	2	3	2n	4			3n	2n	3n	3n		3	2n
Macrobrachium grandimanus	3	3			1				2		1			1n					
Metapograpsus thukuhar	3	1	2	3	2				2				1				1		2
Paryhale sp.				2															
Fish																			
Gambusia affinis	3		3		2						4	3		4	3		4		4
Poecilia reticulata	2		2		2						3	3	4	3	3	2	4	2	3
Oreochromis sp.														4	2				3
Gobidae sp.	1																		
Neomyxus sp.															1				

Table 2. Physical and water quality characteristics of anchialine pools at Kealakehe.

	Area	Depth	Sediment	Temp.		Salinity	D.O.	
Pool	m2	cm	Depth cm	ºC	pH	ppt	ppm	Description
1	16	50	<1	22.3	7.25	13	6.6	Collapsed lava tube rock-rubble substrate
2	20	74	<3	21.4	7.47	13.6	7.1	Collapsed lava tube rock-rubble substrate
3	40	53	<6	21.8	7.4	13.3	7.2	95% *Batis* filled depression complex, 3 open pools. Biogenic sediments
4	16	37	<1	22.3	7.38	13	7.4	80% *Batis* filled depression complex, 5 open pools
5	20	50	<1	22.6	7.39	14.2	7.3	90% *Batis* filled crack complex, 3 open pools
6	9	28	0	22.8	7.3	13.4	4.8	High tide crack pool, rock-rubble substrate
7	2	13	0	23	7.29	13.2	5.5	High tide pool, rock-rubble substrate
8	9	13	0	23.4	7.24	13.4	4.9	High tide pool, fissure depression, rock substrate
9	10	57	<6	22.1	7.46	14	6.9	Sunken depression two pool complex.
10	8	26	<2	22.3	7.45	13.8	4.8	Shaded cave pool, riparian *Sesuvium* northern edge
11	80	58	<15	22.3	7.56	13.2	7.4	97% *Batis* filled depression complex, 2 open pools, *Sesuvium* and *Cyperus*, biogenic sediments
12	15	78	<2	21.2	7.49	12.5	6.5	Collapsed lava tube pool
13	32	72	<4	22.3	7.58	13.6	7.5	Lava overhang, rocky depression, biogenic sediments
14	80	73	<6	23	7.5	14	6.2	70% *Batis* filled complex, 10 open pools, biogenic sediments
15	24	63	<4	22.4	7.52	14.1	7.9	90% *Batis* filled complex, 9 open pools, estuarine influence, biogenic/sand sediments
16	8	25	0	22.6	7.43	13.5	7.5	Dark fissure w/ *Hildenbrandia* epilithon
17	30	62	<10	23.6	7.27	13.7	7.8	Open cave pool, 40% *Cladophora* mat, Biogenic sediments
18	8	34	0	22.2	7.49	13.4	5.8	Rock fissure w/ no vegetation
19	64	75	<24	22.4	7.50	14.1	6.4	95% *Batis* filled depression with 5 open pools, biogenic sediments

4.2.1 Estuary Complex

The estuary at Kealakehe covers an area of approximately 1,120m^2. Its extent to the north includes the open water surrounding Makaopio heiau and the *Batis*-filled complex inland of the heiau. The eastern edge of the estuary is the inland extent of the mangroves. The southern extent runs along the mangrove and is bordered by thick *Batis* overlying rock and sand substrate. The estuary is a shallow water low-lying area with a series of open water pools and is surface connected to varying degrees during the higher high tide periods. Water chemistry and quality is influenced by direct connection to the ocean during medium and high tides mixed with the surface layer of fresher groundwater. Salinity ranged from 29.2 seaward to 14.7, the furthest inland open water exposure. Temperatures ranged from 27.5 to 22.5, and pH from 7.88 to 7.32.
The estuary is in an advanced stage of senescence, filled with *B. maritima* and *R. mangle.* The high density of this riparian and emergent vegetation, provide a barrier to more complete uniform mixing and movement of water and fauna. Sediments are comprised of sand and organic matter and vary in depth from 0cm-22cm. The estuary is distinguished from the anchialine pools not only by similar water characteristics, but similar biological components.

Many of the native species found in the estuary are common to tidepool and nearshore environments such as *Abudefduf abdominalis, Abudefduf sordidus, Sargocentron sp., Acanthurus triostegus,* and *Kuhlia sandvisensis.* Two fish species found at the furthest inland section were *Gymnothorax undulatus* and *Neomyxus leuciscus,* or possibly the introduced mullet *Chelon engeli.* There was an abundance of *T. cariosus* and Grapsid crabs. Unfortunately, throughout the estuary, minnows and tilapia were the dominant species with high population levels.

4.3 Conclusion and Evaluation

A majority of the anchialine pools at Kealakehe are degraded biologically and physically, primarily due the effects of introduced fish and plant species. The 7 pools that are currently devoid of alien fish face a high level of threat due to the proximity of pools that have these fish species. In addition, the pools with intact native biology have relatively low species abundance and diversity compared with other pools in the region and relatively small surface area and volume. They comprised only 10% of the total anchialine pool resource at Kealakehe, and approximately 40% of these were pools visible only at high tide. The high tide pools 6, 7, and 8 are the three to be eliminated by the proposed harbor.

Within the 19 pools, native and non-native fauna included 14 species comprised of 5 fish, 2 mollusca, and 6 crustacea. Algae within the pools primarily consisted of a mixed assemblage of diatoms and cyanobacteria, with several pools dominated by matted filamentous *Cladophora*, sp. The darker cave/overhang pools and high tide pools had epilithic *Hildenbrandia* sp. covering the rock substrate. Riparian vegetation was dominated by introduced species consisting of Pickleweed (*Batis maritima*), Mangrove

(*Rhyzophora mangle*), and Christmasberry (*Shinus terebenthifolius*). Only two species of native plants Akulikuli (*Sesuvium portulacastrum*) and Makaloa (*Cyperus laevigatus*) existed near the pools and comprised only few small patches and a single tuft (respectively).

Fortunately, most of the hypogeal anchialine shrimp have adapted to the presence of minnows by foraging in the pools at night. During daylight hours, only the adult shrimp appear to coexist at low population levels with the smaller *P. reticulata*, but the larger *G. affinis* and *Oreochromis* prevent the daytime appearance of hypogeal shrimp due to predation. The average salinity in Kealakehe pools is relatively high at 13.5 ppt compared to most other pools along the West Hawaii coastline, having an average of approximately 7 ppt. This high salinity appears to be characteristic of this region, and is similar to the average of most pools within the adjacent ahupua'a of Honokohau and Kaloko. This relatively high salinity is the likely reason aquatic insects were not found in any pools at Kealakehe. Though the rare damselfly *Megalagrion xanthomelas* has been observed and collected from Kaloko, a statewide assessment of its range has not found it to occur in water with salinity greater than 3ppt. However, there has been an unsubstantiated occurrence of the nymph in a pool of up to 8ppt (Polhemus, 1995). Another species of concern is the hypogeal decapod shrimp *Metabetaeus lohena.* These shrimp are sometimes predatory on *H. rubra* but are more often opportunistic omnivores similar to *H. rubra.* Predusk and nocturnal sampling at high tide is clearly the optimal method to determine habitat range and population densities for this species. These shrimp were found in 13 of the 19 pools, 7 of which had *M. lohena* only at night. The occurrences of H. *rubra* were found in 16 of 19 sampled pools, 8 of which had Opaeula observed only at night. Consequently, despite having numerous degraded anchialine resources at Kealakehe, there are opportunities for many of the pools to be restored and enhanced to a level where large populations of anchialine shrimp and other native species may return to inhabit the pools as they likely have in the past.

5.0 Framework for Management Program

In order to devise an anchialine pool management program, a set of objectives must be defined. In addition, a monitoring and evaluation program should be in place to detect changes in the physical, chemical, and biological components of the environment, and if necessary, modify the management program to achieve the stated objectives. The proposed list of management objectives and strategies for Kealakehe incorporates those suggested and actively in place by scientists and managers of anchialine systems in Hawaii, some of which include: recommendations by Maciolek in 1987 in an evaluation of anchialine pools at Awake'e, Kohanaiki, and Makalawena; recommendations by Chai, 1988 and 1990 for Ahihi-Kinau, Maui, and 3 National Parks with anchialine resources on Hawaii Island ; management of pools by Chai at Hualalai and Kona Village Resort, 1993-present; management plans developed by Brock for Waikoloa and implemented in 1987, and for Kukio Resort, implemented in 2000; and finally, those proposed by Brock and Kam in their 1997 CNPRSU technical report #112 for Kaloko-Honokohau National Historical Park. Additionally, these objectives and strategies should be taken as a preliminary framework or first step, not a static plan. Numerous valid interests toward the health and benefit of the anchialine pools and broader coastal ecosystem must be taken into account as the final objectives and strategies are formulated.

5.1 Management Objectives

Objective 1	To preserve, maintain, and foster the long-term health and native ecological integrity of anchialine pools at Kealakehe.
Objective 2	To protect and promote cultural practices and traditions surrounding anchialine resources at Kealakehe.
Objective 3	To provide education, interpretation, and interactive opportunities for the community to learn about and appreciate the anchialine resources.
Objective 4	To acquire a pond manager to implement the program, conduct monitoring, research, and reporting, and provide education to the community about anchialine and estuarine resources.

5.1.1 Objective 1 To preserve, maintain, and foster the long-term health and native ecological integrity of anchialine pools at Kealakehe.

To achieve this and allow all the other objectives a path toward success, the central component of the management program must involve the restoration and enhancement of the existing degraded pools. The existence of anchialine pools is ephemeral, and the senescence process that leads toward their ecological degradation and in filling, is dramatically accelerated due to the presence of alien species in and around the pools. The first stage of restoration will involve the removal of alien fish and plant species, and the removal of sediments from the pools and estuary. The consequence of this will be the natural return of native aquatic fauna to the pools very quickly. They are essentially "waiting in the wings" to reemerge from the subterranean habitat. The second stage will be the reintroduction of native plant species that formerly inhabited the pools and pool complexes. Again, as with the fauna, many native species will reemerge in the absence of

invasive plants, but some natives will need to be reintroduced to more quickly dominate the riparian and emergent habitat. Concurrent with the restoration should be a defined maintenance program to protect the ecological integrity of the system.

5.1.2 Objective 2 To protect and promote cultural practices and traditions surrounding anchialine resources at Kealakehe.

Concurrent with the ecological restoration should be the repair or reconstruction of the cultural features that were associated with the pools and estuary. Evidence suggests that early Hawaiian inhabitants used these pools. The pool management plan should incorporate some form of traditional use and management based on the testimony of lineal descendents of the ahupua'a if possible, or at least descendents from this region. The use of anchialine resources obtained from healthy native ecosystems can be accomplished on a sustainable basis without adverse impacts to the system. Hawaiians of the past considered anchialine pools a significant asset, a gift, and they were carefully maintained. This same respect and stewardship should be encouraged for pools at Kealakehe.

5.1.3 Objective 3 To provide education, interpretation, and interactive opportunities for the community to learn about and appreciate the anchialine resources.

Anchialine pools as an educational resource is important for many reasons. The pools are rare, accessible, and fascinating, allowing educators a unique opportunity to solidify concepts of science, math, and culture through their study. The pools allow people to learn about, experience, and appreciate a rare and unique habitat up-close. Understanding and appreciation of anchialine ecosystems lead to respect, and help foster the ideals and actions toward preservation and stewardship of the resource for many generations to come. Interpretive signs, tours and activities should be designed with this concept in mind.

5.1.4 Objective 4 To acquire a pond manager to implement the program, conduct monitoring, research, and reporting, and provide education to the community about anchialine and estuarine resources.

The designated anchialine pool manager should be well qualified and responsible for implementing the anchialine resource management program. This person will plan and oversee all the activities needed to fulfill the objectives. The manager will coordinate all aspects of the monitoring program and evaluate the results. As an ambassador to the public for the natural resources of Kealakehe, the manager must embrace the concepts and values of malama and pono in their management approach.

6.0 Water Quality and Aquatic Life Monitoring Plan

Environmental monitoring is vital as an early warning system to detect potential environmental degradation. A series of quantitative baseline analysis of the physio-chemical and biological components within the project site will provide a standard by which the effects of the development, anthropogenic activities, and natural phenomena on the environment can be measured. Changes in groundwater quality may or may not impact biological communities in the anchialine and estuarine environment. In either case, it is important to understand these relationships to effectively manage the resource. If there is significant deviation from the baseline especially in regard to nutrients, pathogens, and toxins, a mitigation plan to determine the cause and take decisive appropriate action should be implemented.

Water chemistry and sediment analysis should be undertaken in accordance with recommendations for groundwater and anchialine pool monitoring by the West Hawaii Coastal Monitoring Task Force, 1992. The monitoring protocol established in this document provides a complete and valuable management tool in helping to protect groundwater, anchialine, and marine resources. In conjunction with physio-chemical monitoring would be a quantitative analysis of biological communities. Determination of abundance, distribution, diversity, and physiological health of the populations should be key elements to the biological monitoring plan.

6.1 Monitoring Frequency

Using the 1992 monitoring protocol guidelines the monitoring program should be undertaken during 3 phases of the Kona Kai Ola project; 1) pre-construction to establish a comprehensive baseline analysis, 2) during construction as a continuation of monitoring protocol established during baseline analysis, and 3) post construction, or during the operations phase of the project. All monitoring should take place at least quarterly for water chemistry/quality and for biological communities as long as construction and pool restoration efforts are taking place. Thereafter, semi-annual monitoring should be adequate up to at least 5 years following construction activities. Extreme storm or other natural or anthropogenic events should also trigger a sampling analysis. Sediment sampling should be undertaken yearly if there is no indication of contamination by toxic pollutants. If contamination is discovered, monitoring should continue on a quarterly basis until there is no indication of contamination.

7.0 Mitigation Plan Recommendations

Based on the scale and scope of the proposed project, it is inevitable that there will be impacts to the anchialine pools, estuary, and marine environment. Managers of the proposed project have an opportunity to learn from, formulate plans, and make decisions based in some part on the mistakes and successes of other developments and resource management projects along the coast of West Hawaii. Much of the success in avoiding or mitigating detrimental environmental impacts will depend on the cooperation of the developer, landowners, and experts or persons knowledgeable in the field of environmental systems related to the project site. The following mitigation recommendations are a first step and a guideline for discussion and planning. The precise details of the plan and timeline will need to be determined at a later date.

7.1 Creation of New Anchialine Pools

A problem with the plan to restore existing degraded anchialine pools at Kealakehe is the proximity and high level of connectivity of some pools to the estuary. This connectivity will not permit the use of piscicides to eliminate alien fish, due to the possibility of harming marine organisms. Therefore, they cannot be restored to their former natural state dominated by native species. Additionally, the planned harbor is expected to eliminate three high tide anchialine pools that contain *H. rubra* and *M. lohena.* As a response to this loss of habitat there is significant opportunity to create new anchialine pools and greatly expand the native habitat and resource. It has been demonstrated at several projects in West Hawaii that anchialine pools can be created and will be colonized with a full compliment of anchialine species endemic to the area (Brock and Norris, 1988, Chai pers. observation). Anchialine pools are considered focal points of higher productivity relative to the subterranean groundwater habitat around them. Their productivity promotes an increase in population levels of anchialine species within the pools themselves and throughout the subterranean habitat surrounding them. In regard to decapod crustaceans, there exists a positive linear relationship between the size of the anchialine pool and the population of shrimp that inhabit them. A reconnaissance of the area indicates numerous potential sites within the project area to create anchialine pools wherever the land surface is within a few meters from the water table. In addition to increasing habitat productivity for native fauna, anchialine pools are functionally wetlands and have the ability to sequester and convert dissolved organic nutrients and other pollutants from the groundwater before they enter the marine environment (Brock and Kam, 1997, Ogden and Campbell, 1999).

7.2 Water Resources Protection and Mitigation

7.2.1 Bioretention

There is a high probability that nutrients and other potential pollutants will runoff landscaping and impermeable surfaces such as roadways and parking lots during medium or high rainfall events. Some of these pollutants will enter the groundwater table and into anchialine pools and ultimately the ocean. As an alternative to directing runoff into the ground through drywells, storm water should be directed into bioretention areas such as constructed surface or subsurface wetlands, vegetated filter strips, grass swales, and planted buffer areas. Storm water held and moved through these living filter systems are essentially stripped of most potential pollutants, and allowed to slowly infiltrate back to the groundwater table (Innovative Technologies for Storm water and Wastewater Workshop, 2005). Bioretention is a BMP (Best Management Practice) that would be a highly appropriate application for the proposed development. Furthermore, BMPs utilized in series may incorporate several storm water treatment mechanisms in a sequence to enhance the treatment of runoff. By combining structural and/or nonstructural treatment methods in series rather than singularly, raises the level and reliability of pollutant removal. Another means to reduce the potential for groundwater contamination is to increase soil depth above the standard in landscaped areas. This will allow chemicals to be held in the soils longer for more complete plant uptake and breakdown of these chemicals by soil microbes. A specific guide for chemical application by landscape maintenance personnel will be a beneficial tool to help avoid contamination of groundwater resources.

7.2.2 Salinity Adjustment

In the 2006 assessment by Ziemann regarding the impact to the southern pools from the proposed construction of the harbor, he stated that this construction would cause the salinity in the anchialine pools to become equivalent to the ocean at 35ppt. The anchialine biology would then soon perish. There is currently a level of uncertainty by professional hydrologists as to the exact movement of surface groundwater and a final determination of anchialine salinity following the harbor construction. The dynamics of groundwater movement through a porous lava medium both seaward and laterally along the coastline is an inexact science. This is compounded by the variations in water density, including stratification of salinity within the proposed harbor and capillary movement of low-density surface water through the substrata. The assessment that all anchialine pools will be barren with the construction of the harbor may be premature. *H. rubra* are routinely drawn from high salinity wells at 30 – 32 ppt and survive in this salinity for years. As mentioned early in this document, high populations of *H. rubra* and *M. lohena* have thrived and reproduced in pool salinities of 27ppt. If the pools do become full strength seawater at 35ppt, there exists uncertainty on the long-term effects to anchialine organisms, since there are no long-term studies or examples of native anchialine ecosystems at 35ppt. Native anchialine pool vegetation also has relatively high salinity tolerance. Akulikuli will grow as a riparian plant and *R. maritime* will thrive as an aquatic plant at a salinity of 27ppt. *Bacopa monieri* and Makaloa will grow in salinities of up to

20ppt. Other than Aki aki, (*Sporobolis virginicus*), and Ohelo kai (*Lycium sandwicense*) no other native aquatic or riparian flora will likely thrive among seawater pools.

If the salinity were expected to rise to 35 ppt, a possible mitigation would be to surcharge man-made anchialine pools created adjacent to or in the vicinity of natural pools with low salinity well water. If sufficient volume is used, it is theoretically possible to lower salinity in adjacent natural anchialine pools. This surcharge method has been successfully used to raise salinity in anchialine pools and cause the salinity rise in adjacent pools of at least up to 10 meters away. Surcharging with low salinity should work as well or better since the lower density water will essentially float atop the higher salinity water at the surface layer, and move throughout the complex of natural pools. Surcharging may also be a viable mitigation to dilute and more rapidly disperse any pollutants that may be detected in the pools.

If the harbor is to be a receptacle for the discharge of seawater from a man-made lagoon, it may help to maintain lower salinity in pools if the discharge of this seawater is place at the bottom of the harbor, thereby preserving the stratified layer of lower density surface water within the harbor. If the porosity of the lava near the surface of the groundwater table is sufficient, it may allow this low salinity surface water to move laterally through the area of anchialine pools.

7.2.3 Groundwater and Anchialine Pool Contamination Response

The response plan to contamination of the groundwater should be designed to prevent the negative impact to aquatic communities and human public who use the pools. Mitigation should focus on halting and reversing the source of contamination and its effects on living communities. Environmental problems that will trigger notification of the Developer and appropriate agencies, and require immediate mitigation and corrective action to halt the source of contamination, include: 1) the finding of pesticides or other toxic pollutants within the groundwater, anchialine pools or pool sediments; 2) a significant deviation in dissolved nutrients above normal baseline parameters; 3) a significant decline in population or a serious wide-spread health problem in the biological components that comprise the anchialine or estuarine habitat.

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Appendix I

Zone of Mixing (ZOM) Report

By Oceanit

Zone of Mixing (ZOM) Report
Resulting From Construction and Operation of the
Expanded Honokohau Harbor
Kona, Hawaii

Literature Review and Report For

Jacoby Development, Inc.

By

Oceanit Laboratories, Inc.

November 2006

KONA KAI OLA DEVELOPMENT: ZOM REPORT

1. Purpose

The purpose of this study is to develop an effective estimate of mixing levels and water quality variations in the nearshore area adjacent to Honokohau Harbor entrance in order to determine the approximate extents of the zone of mixing (ZOM). The existing zone of mixing characteristics will be used to assess impacts from the proposed marina expansion and the sea water discharged from the project water features.

2. Method / Procedure

General conditions of the study area appear to be well documented, and a variety of data sets such as bathymetry and aerial imagery were readily available. This information was assembled and analyzed prior to any major planning of field deployments in order to focus our attention in the most effective direction. The Honokohau Harbor vicinity has been the subject of various studies in the past, and pertinent information has been referenced from them as appropriate in this report.

Due to the limited scope of the present effort, it was only possible to physically study the area for a very limited duration (48 hours) and therefore required strategic planning of when to deploy instrumentation and conduct measurement activities. It was unanimously agreed upon that a period of maximum outflow from the harbor, such as the falling of a spring high tide, would be an appropriate duration in which to collect measurements as related to a zone of mixing study. Subsequent results and conclusions are not assumed to be representative of typical conditions for this area, but should be fairly representative of worst case discharge rates such as during spring tides, during an ebbing higher high water.

In-situ data collection at the project site was determined to be a three part process, consisting of longer-duration time-based current measurements in the harbor mouth, far-field current measurements during extreme out-flow conditions, and CTD (Conductivity-Temperature-Depth) profiles at multiple nearshore locations outside of the harbor during extreme out-flow conditions.

Time-based current measurements were recorded through the use of an Acoustic Doppler Current Profiler (ADCP) which was deployed near the center of the harbor entrance over a period of approximately two days during a spring tidal cycle (10-12 May 2006). This time frame was specifically chosen in order to gather data during maximum tidal displacements which in turn should yield the highest flow rates in the channel. The instrument recorded water velocities in three dimensions at five horizontal strata or levels (cells) in the water column and was programmed with a one-minute averaging interval and a five-minute sampling interval. Additionally, the ADCP was set to record the pressure series (hydrostatic pressure) which is directly related to water elevation (i.e., tidal height), which gives us a direct correlation between current speed/direction and tidal condition.

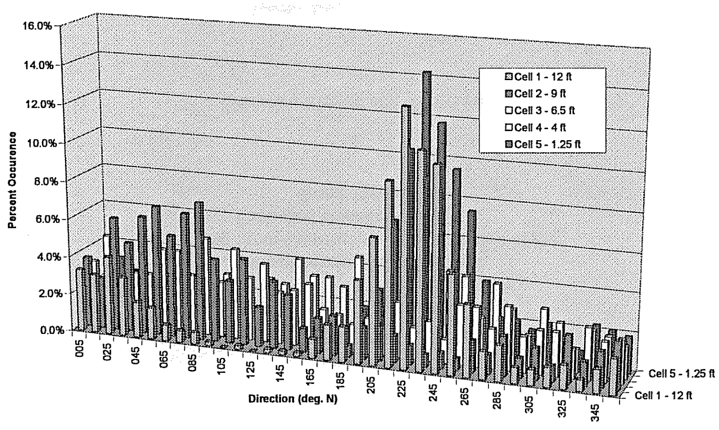
Far-field current measurements were acquired through the use of drogues, which in this case were simply a floating marker attached to a submerged drag chute which is in turn transported along the with the water in a current. In contrast to the ADCP which measures currents over time at a singular location, drogues act as tracers and track the current during a period of time at multiple locations over an entire area as the out-flowing water disperses. Drogues were deployed on 11 May 2006 near the harbor entrance roughly one hour after the turn of the higher high tide (i.e., water is now flowing back out of the harbor basin). Drogue positions were tracked manually by boat and logged every 30 minutes, where a position was fixed via GPS receiver and a sounding was recorded from the fathometer simultaneously. This data was later compiled into a track line trajectory and plotted on bathymetric charts and aerial imagery to analyze the horizontal distribution of the out-flowing current.

Temperature and salinity profiles were measured from the surface by boat at every logged drogue position by 'casting' or lowering a CTD from the sea surface to the bottom, or to a maximum depth of 40 feet. These profiles were recorded during the same time interval as the drogue tracking in order to define the vertical structure of the out-flowing water. An additional horizontal surface transect was recorded approximately 20 feet offshore along the shoreline, continuing across the entrance channel and along the shoreline on the other side. This was completed during an incoming tide from lower low to higher high for a look at baseline or low out-flow conditions.

3. Results

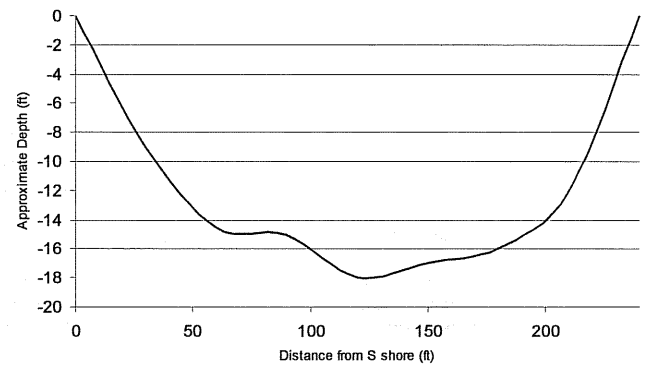
Directional current data in the harbor channel was collected in order to make an informed estimation of the volume of brackish water from the artesian springs within the basin

FIGURE 1. Honokohau 2-Day Current Directions



exiting the harbor to the open ocean. A bathymetric cross section of the harbor channel near the ADCP deployment site, along with the current velocity data series allows for calculations of estimated volumetric flow rates within the individual cells measured by the ADCP. A statistical analysis of the data showed an unexpected amount of directional variation within the data set as seen in Figure 1. It was predicted that current directions would largely be centered about two bearings corresponding to the approximate alignment of the channel entrance (070° in and 250° out). Cells 1 and 5 do tend toward this condition but cells 2 through 4 show significant spreading. It is theorized that this spreading or variation in direction is most likely a result of vortices or eddies occurring in the channel due to current flow around the sharp corners and the relatively vertical sides of Honokohau Harbor's channel walls. As the current exits the harbor, it is essentially forced to make subsequent right angle turns, in opposing directions (which some refer to as a "dog-leg"), likely creating some type of flow disturbance in the channel as suggested by the direction data. Due to their rotational nature, the eddies or vortices could well account for the contra-flow and lateral flow current velocities that are present in the data set. Although unexpected, this finding does not preclude the validity of the data and a reasonable estimation of the resultant net outward current can still be estimated. To accomplish this, the velocity structure in the water column must be simplified or resolved to determine the resultant components flowing only in the direction of exiting the harbor, which is approximately 250°. By determining peak outflow velocities for each cell or depth layer, and knowing the cross sectional area of the entrance channel (see Figure 2), we can now estimate an average maximum flow rate. Additionally, by superimposing the salinity profile near this location, we can further estimate the fraction of this flow that is brackish water (see Figure 5).

FIGURE 2. Honokohau Entrance Channel Cross Section at Narrowest Point



The drogue study results give us a general indication of the horizontal dispersion pattern of the water as it exits the harbor mouth area during an extreme tide. Drogues were

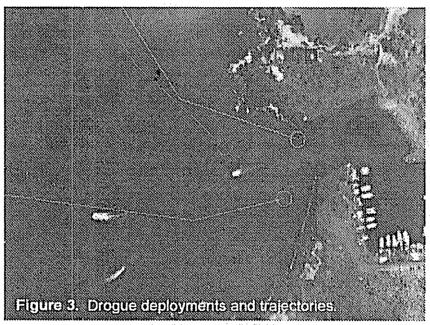
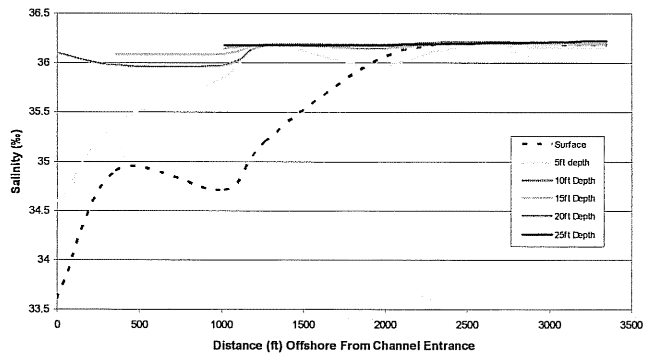


Figure 3. Drogue deployments and trajectories.

deployed near the harbor mouth at approximately the same time at the four locations shown in Figure 3, indicated by the circles at the start of each trajectory line. The release time was about one hour after the start of a large tidal drop of approximately two feet, which is in the maximum spring tidal range for this geographic location. Results of the drogue study suggest a general northward drift of the surface layer at around 7 to 8 cm/s (0.15 knots) for the area adjacent to and immediately north of the harbor entrance channel. Additionally, it indicates that for parcels adjacent to and immediately south of the entrance channel, a west by northwest drift of 9 cm/s or more exists. Momentum from the exiting current flowing from the harbor during this time likely imparts a westerly or offshore component to the nearshore flow pattern, but in general it appears that a south to north net littoral transport is the dominating influence at this location. Existence of this northward surface current is supported by the results of previous studies performed at Honokohau Harbor.

Salinity profiles, or CTD casts were recorded at twenty-two locations outside the harbor entrance during the falling tide and yielded generally predictable results. Primarily, it was found that there is a well stratified layer of brackish water with salinity values between 33‰ and 34‰ (parts per thousand) which was observed in the top 5 feet of water just offshore of the harbor mouth. CTD casts further from the entrance (in a

FIGURE 4. Salinity Profile Along Entrance Channel Centerline: Honokohau Harbor

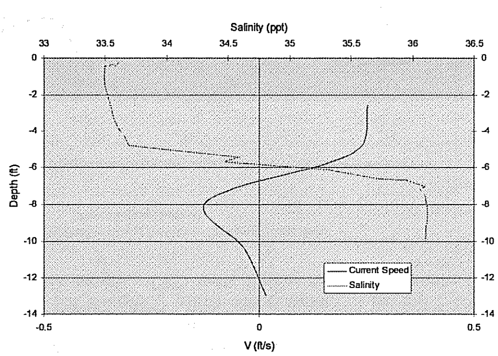


direction moving offshore) showed progressive increases in the surface layer's salinity and a much more gradual haline gradient between it and the underlying seawater. In other words, the brackish surface layer appeared to be mixing rapidly as it exited the channel. Figure 4 above is a graph of salinity plotted against distance from the harbor entrance, sorted by depth layer (cells). For example, the surface layer salinity starts off at nearly 33.5, quickly increases to 35 in the first 500 feet, slowly decreases to about 34.75 at 1000 feet, and then fades back to an ambient salinity range by a distance of 2000 ft. This plot gives us an indication of the degree of stratification that is occurring as a function of distance from the source, which is in turn related to the rate at which it is mixing. Salinity measurements were acquired with the same instrumentation at several control locations away from the harbor approximately one mile offshore of Honokohau. Physical samples were also collected at the same control locations and sent to an independent lab for testing. After analysis, lab and in-situ measurements were determined to be in good agreement, and resulting ambient seawater salinities for this area were found to be around 36‰.

4. Discussion

Following analysis of data collected during the present effort and referring to archival reports of the area, it is possible to draw some useful observations in terms of identifying the extents of the zone of mixing produced by the natural seepage of brackish water from inside Honokohau Harbor into the open ocean.

Figure 5. Current Speed and Salinity v Depth



Outflow: Using data points for all times of ebbing tide during the period, a statistical distribution of direction and magnitude was developed. From the distribution, it was found that the outflow current is in the range of 0.15 to 0.25 knots (0.25 to 0.42 ft/s) for 50% of the time at the surface. The full range is from 0.0 to 0.6 knots. Figure 5 at right illustrates the relationship graphically, where the salinity profile and velocity profile are overlaid for the same instant and location within the harbor entrance channel, where positive velocities are flowing out of the harbor and negative velocities are flowing inward. The graph reflects an arbitrary reading an hour into the falling tide and is probably representative in terms of estimating the true output velocity structure and stratification in the entrance. The brackish water layer is clearly visible by the sharp break in the salinity profile at a depth of 5 feet. The surface layer appears to move uniformly at approximately 0.25 ft/s, which would produce a brackish water discharge of approximately 257 ft^3 per second.

Extent of Mixing Area: The measurable extents of the brackish outflow plume were estimated horizontally by using drogue and salinity profile data. It was found that the brackish water on the surface was near completely mixed at a maximum distance of slightly more than 2000 feet from the harbor mouth, and in some places much closer. The fresh water output seems to be concentrated in a tongue extending from the entrance channel as it exits the harbor, as suggested by the contour plot in Figure 6. Also evident in this figure, is the northward drift of the plume as it becomes entrapped in the existing northerly current offshore of the site (identified by the bending of the contours towards WNW). As the brackish water seeps into the harbor from the porous rock, it quickly floats to the surface and forms a thin, essentially homogenous layer due to density differences with the heavier ambient seawater. As a result, when the brackish water exits the harbor it is most effected by surface conditions. Additionally, due to the layer's relatively small thickness of about 5 feet and the surrounding seafloor's depth of 12 to 15 feet or more, there is minimal chance for contact between the brackish water and the seafloor. The exception is for shallow areas near the entrance channel walls, where the

brackish layer will intersect with the shoreline and possibly the bottom (shoreline areas near red and orange bands in Figure 6 below).

Tidal Effects on Entrance Channel Currents: For typical tidal exchange in and out of a harbor, one would expect a direct relationship between in-flow and a rising tide, and out-flow with a falling tide. In the case of Honokohau Harbor, the data clearly shows an out-flow current for a significant portion of the rising tide as well. This indicates that the harbor is discharging into the ocean to some degree at all times, and is due to the input of fresh/brackish water seeping into the harbor at a rate greater than that of the seawater entering through the channel during a rising tide. This has been documented in previous studies and is confirmed by our results here.

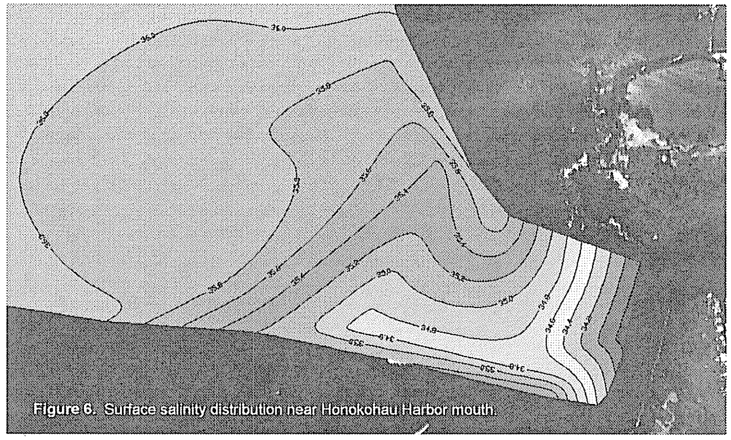
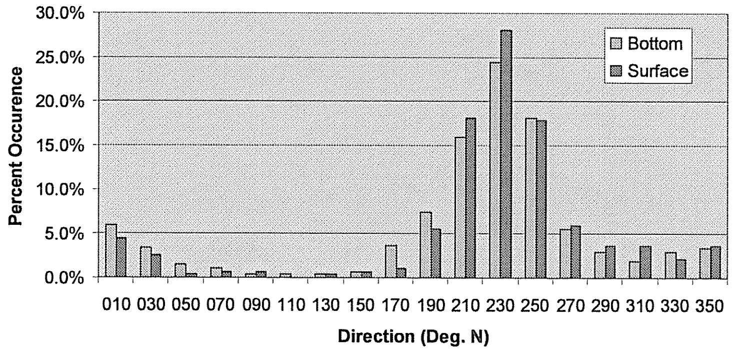
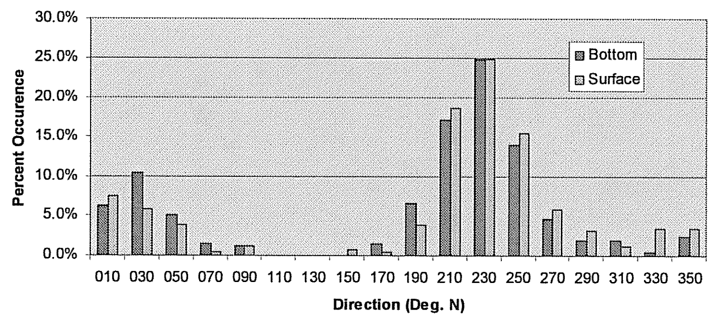


Figure 6. Surface salinity distribution near Honokohau Harbor mouth.

Falling Tide



Rising Tide



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Appendix J

Wave Penetration Study

By Moffatt & Nichol

KONA KAI OLA WAVE PENETRATION STUDY

Prepared by

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August 2006

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Appendices

1.0 Introduction

The Kona Kai Ola project entails the expansion of an existing small boat harbor, Honokohau harbor, located on the western coast of the Island of Hawaii, midway between Keahole Airport and Kailua (Figure 1). While the western coast is considered the leeward coast with respect to the prevailing north easterly trade winds, the project site is still open to waves from the directional sector 225^0N - 315^0N going clockwise as discussed in Section 2.1.

1.1 Purpose

The purpose of this study is to determine the wave characteristics within both the existing harbor and the proposed expansion basin. A comparison of the two wave conditions will help ascertain the wave impacts on the existing harbor that would result from the proposed expansion.

1.2 Scope

Toward this end, a numerical modeling approach comprising the following tasks has been adopted:

1.2.1 Establish the offshore wave climate to be used as inputs to the wave models;

1.2.2 Collate the relevant tide and bathymetric information for preparing the model bathymetry and domain;

1.2.3 Set up the model input and boundary parameters;

1.2.4 Conduct model runs to determine the degree of wave penetration/agitation in the harbors;

1.2.5 Compare the resulting wave patterns and determine the wave impacts due to the proposed expansion; and

1.2.6 Recommend appropriate action.

This report pertains only to the wave penetration issues of the project while other components such as marketing, flushing analysis, sedimentation, etc. are addressed separately. Section 2 of this report will describe the project setting including the sources of data used, followed by an elaboration of the modeling approach. The results of the modeling work are then presented, leading to the determination of the wave impacts on the existing harbor. The report concludes with recommendations based on the results of the wave modeling work.

2.0 Project Description

The Honokohau harbor faces Honokohau Bay within a smaller embayment bounded by Maliu Point to the north and Nolo Point to the south (Figure 1). The shoreline is fringed by low-lying reefs with a gap accommodating the entrance channel that trends roughly SW-NE before it turns nearly normal toward the SE to join the outer harbor. A connecting channel extends from the outer harbor along the W-E direction into the inner harbor also oriented in the same W-E direction for a total distance of about 400m. According to NOAA Chart 19327 (West Coast of Hawaii: Cook Point to Upolu Point, 1997), the outer basin is 13ft deep, the same depth as the entrance channel while the connecting channel and the inner basin vary from 6 to 10 ft in depth, all referenced to MLLW. Both sides of the entrance channel are lined with riprap with the northern side featuring an additional cut slope to serve as a wave dissipating feature.

The proposed harbor expansion extends from the southern end of the outer basin southward for a distance of about 850m (Figure 2). There are two lateral sub basins, near the mid section of the exterior side and the other at the southern end that stretch about 350m across. The proposed water depths vary from 8 ft to 13 ft MLLW.

2.1 Bathymetry

The coastline in the vicinity of the project area was digitized from NOAA Chart 19327 downloaded from http://historicals.ncd.noaa.gov/Sid_image/ while the depths of the surrounding area were interpolated from the electronic hydrographic surveys for the area archived at the GEODAS website (http://www.ngdc.noaa.gov/mgg/geodas/geodas.html).

2.2 Tide

Tidal datum information was obtained from the NOAA website (http://tidesandcurrents.noaa.gov/). The project area experiences a mixed tide regime with the tidal datum relationships shown in Table 1 based on Station 1617433 (Kawaihae, Hawaii Island) located at 200^0 2.4'N and 1550^0 49.9'W:

Table 1 Tidal Datum Relationships

Mean Higher High Water (MHHW)	= 0.653m
Mean High Water (MHW	= 0.500m
Mean Sea Level (MSL)	= 0.283m
Mean Tide Level (MTL)	= 0.277m
Mean Low Water (MLW)	= 0.054m
Mean Lower Low Water (MLLW)	= 0.000m

2.3 Offshore Waves

The offshore wave climate was characterized by hindcast wave data (1995 – 2004) for the Pacific Ocean from the Wave Information Study (WIS) website maintained by the US Army Corps of Engineers (http://frf.usace.army.mil/cgi-bin/wis/pac/pac_main.html). While measured wave data are available from offshore buoys operated by NDBC, they are located quite far from the project site. NDBC buoys 51003 and 51002 are shown in Figure 3. More importantly, the buoys are non-directional and hence do not yield any directional information relevant to the wave exposure window for the project site. Hence, the offshore wave statistics are derived from the wave roses generated from the WIS data shown in Figure 3. The wave roses indicate that within the wave exposure window, the larger and more frequent waves tend to come from the NW and WNW sectors.

Another noteworthy characteristic of the deepwater waves is the dominance of long-period swells as seen from the wave statistics in Figure 4 (within the red lined box). This is true especially for the wave approach directions within the wave exposure window. In terms of wave height, while the most frequent waves are in the 1 - 2m range (operating wave climate), those within the 2.5 - 4m range occur for more than 3% of the time and could be considered as the storm wave condition to characterize the response of the harbor basin (within the black lined boxes in Figure 4). These directional and wave period characteristics are considered in the selection of wave scenarios for wave modeling discussed in Section 3.

3.0 Model Description and Approach

The Nearshore Spectral Wave (NSW) and Boussinesq Wave (BW) modules were used in tandem to assess the degree of wave agitation in the marina where the NSW module is used to transform waves from the offshore to the nearshore area while the BW is used to simulate detailed wave propagation into the basin.

The wave model MIKE 21 NSW describes the propagation, growth, and decay of short-period and short-crested waves in nearshore areas. The effects of refraction and shoaling due to varying depth, local wind generation, and energy dissipation due to bottom friction and wave breaking are included, as well as effects of wave-current interaction. Basic output from the model includes significant wave height, mean wave period, and mean wave direction. In addition, spectral output data in the form of the distribution of wave energy with direction can also be obtained. The NSW model does not consider reflection, diffraction, or frequency dispersion

The MIKE 21 BW model solves the enhanced Boussinesq equations that have been extended into the surf zone by the inclusion of wave breaking and moving shoreline. It is capable of reproducing the combined effects of refraction, diffraction, partial reflection and transmission, non-linear wave-wave interaction, frequency spreading, and directional spreading.

3.1 Wave Transformation Using the NSW Module

The NSW model domain covers an area of 3km (grid size = 2m) by 5km (grid size = 8m) as shown in Figure 5. The wave inputs at the offshore (western) boundary are for a constant significant wave height of 2m and a constant peak wave period of 13s, but at various directions bracketed by the wave exposure window. The results are shown in Figure 6 in terms of wave height contours and directional vectors. The results show waves are refracted such that at the white line, which marks the position of the boundary of the detailed BW model (see Section 3.2) and which corresponds to an averaged depth of 12m, the wave directional vectors (black arrows), despite the considerable spread at the offshore boundary (225° – 315 ° N) are bundled into a much narrower directional sector of 260 ° – 280 ° N. In addition, the direction 270°N results in the highest wave condition just offshore of the entrance. These results led to the adoption of the approach wave direction of 270 ° N in BW model as representative of the prevailing incident wave condition.

3.2 Wave Penetration Using the BW Module

Unlike the NSW module that operates in the frequency domain and is a phase-averaging module, the BW module operates in the time domain and its phase-resolving capability places a high demand on fine resolution in both space and time. Therefore in order to adequately resolve the incident wave length, the BW model domain has a very fine spatial resolution of 1m and covers an area of 920m along the E-W (x-axis) by 1170m along the N-S (y-axis) in order to accommodate the proposed expansion as shown in Figure 7. For runs involving the existing basin only, the proposed expansion area is simply turned into land and removed from the computation.

It can be seen from Figure 7 that the open water boundary has been replaced by a thin veneer of land points to facilitate the specification of the internal wave generation line (IWGL). The internal wave generator line (IWGL) is placed parallel to the y-axis which has an average depth of 12m. The IWGL and the two open water areas at the north and south ends are defined as wave absorbing boundaries while the internal boundaries of the basin (e.g., riprap, vertical seawalls, etc.) are lined with grid points to simulate the different reflection characteristics of the bounding surfaces.

The incident waves are specified as time series of flux densities and surface slopes generated by a MIKE21 Toolbox utility (random wave generation) based on the TMA spectrum. Consistent with the dominance of long-period swells and the NSW run results as discussed in previous sections, the following wave inputs were specified in generating the incident wave conditions:

a) Type of directional distribution = $\cos^{10}n$ (swells)

b) Peak wave period = 13s

c) Minimum wave period = 9s

d) Main wave direction = 270^0n

e) Maximum wave direction deviation = +/- 30^0

f) Significant wave height = 1m, 2m, and 3m.

Based on the nature of the bounding shoreline, the reflection coefficients characterizing these boundaries assumed an impermeable core were assigned. The resulting reflection coefficient at the internal land boundaries is a function of the local wave height, wave period, water depth, and number of grid points used to define the reflection.

Since wave breaking is included in order to better represent the nearshore wave dissipation regime, high frequency instabilities due to the uprush and downrush at the shoreline are filtered out using an explicit low-pass filter. The filtering also helps dissipate the wave energy in the area where the surface roller cannot be resolved. As recommended (DHI, 2004), a filter coefficient of 0.25 is specified near the shoreline up to a cutoff water depth of 1-2m. Elsewhere in the water area the filter coefficient is kept to zero, signifying no filtering.

For all runs, a time step of 0.05s is used. The length of each simulation is 35 prototype minutes (corresponding to 42001 time steps), which is sufficiently long for the wave heights in the basin to adjust to the boundary conditions and bathymetry

4.0 Existing Harbor Conditions

The results of the BW runs for the case of the existing basin are shown in Figure 8 (left) for the case of an incident wave height of 1m. Generally the waves are reduced by half after the entrance channel and decrease further to 0.2-0.3m at the center of the outer basin and the bulk of the inner basin. The periphery of both the outer and inner basin, more so for the former, experiences higher wave heights due to wave reflection. Wave heights within the connecting channel are also higher at 0.4-0.5m compared to the two basins.

There seems to be a tendency for locally higher wave height near the entrance at discrete points, the furthest in being on the south bank of the entrance channel. This may be corrected by decreasing reflection there to augment wave dissipation. However, selection of the appropriate value hampered by the lack of field wave data to substantiate the degree of enhanced wave dissipation required.

As seen from the visual comparison in Figure 8, which displays the wave condition for the proposed basin expansion on the right, the basin expansion has the overall effect of reducing wave activity within the outer and inner basins, including the connecting channel. This is further illustrated by the profile presentation in Figure 9.

Figures 10 and 11 display the run results for the case of a 2m incident wave height, which supports the same general trend of reduced wave height as before. The same trend is seen for the storm wave scenario (H = 3m) as evident from Figs. 12 and 13.

The trend for the case of shorter period waves, which no doubt occur less frequently, is illustrated in Figs. 14 and 15 for H = 2m and a wave period of 9s. Again, there is a general reduction in wave height in the existing basin as a result of the proposed basin expansion.

5.0 Impacts of Proposed Project on Existing Harbor

While the wave impacts of the proposed harbor expansion are tracked through profile changes, this Section provides a synoptic view of the differences on a basin-wide scale as seen in Figs. 16 and 17. For each of the four scenarios, the net difference in wave height within the existing basin is computed. While there are discrete areas where the wave height has actually increased, these increases are small, being less than 0.1m. On the other hand, the main bulk of the existing basin experiences a decrease in wave height as much as more than 0.3m, especially at the southern border of the outer basin. This is primarily due to the fact that the same amount of incident wave energy is now dissipated through interaction with the additional frictional surfaces (both sides and bottom) of the proposed basin expansion.

6.0 Summary and Conclusions

Based on the numerical modeling approach adopted herein comprising the use of the Nearshore Spectral Wave (NSW) module and the Boussinesq Wave (BW) module in tandem, the wave height changes from the offshore boundary to the nearshore area, and the subsequent wave penetration into the basin area have been computed. The incident wave field at the offshore boundaries has been evaluated based on wave hindcast data and characterized as long period swells. The wave transformation as modeled by the NSW module indicates the waves refract such that they approach the nearshore area from a very narrow directional sector centered at 270^0N.

Using the BW module, the tracking of these long period swells indicates more than half of the wave height is lost at the outer basin with a further drop in the inner basin.

Based on four representative wave scenarios (H_{mo} = 1, 2, and 3m, all with T_p = 13s and H_{mo} = 2m with T_p = 9s), results indicate a consistent reduction in the wave height in the existing basin area with the proposed basin expansion. This is primarily due to the fact that the same amount of incident wave energy is now dissipated through interaction with the additional frictional surfaces (both sides and bottom) of the proposed basin expansion. Hence, the overall wave impacts consequent upon the proposed basin expansion can be considered as positive since the existing harbor will experience less wave agitation.

7.0 References

Danish Hydraulic Institute (2005a). User Guide/Scientific Documentation for MIKE 21 Nearshore Spectral Wave (NSW) module.

Danish Hydraulic Institute (2005b). User Guide/Scientific Documentation for MIKE 21 Boussinesq Wave (BW) module.

Hydrographic Survey: http://www.ngdc.noaa.gov/mgg/geodas/geodas.html

Nautical charts: http://historicals.ncd.noaa.gov/Sid_image/

Tides: (http://tidesandcurrents.noaa.gov/).

Wave hindcast data from the Wave Information Study (WIS): (http://frf.usace.army.mil/cgi-bin/wis/pac/pac_main.html

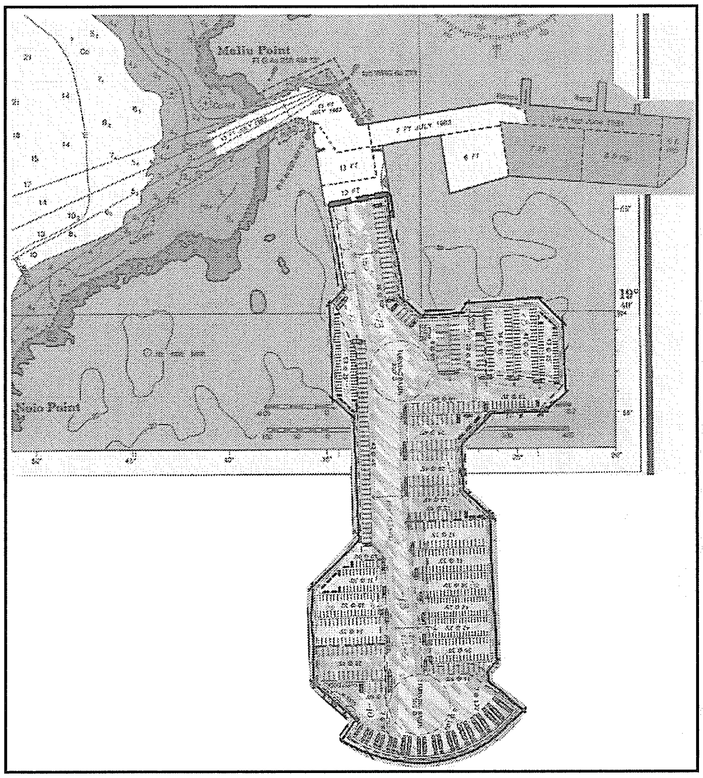
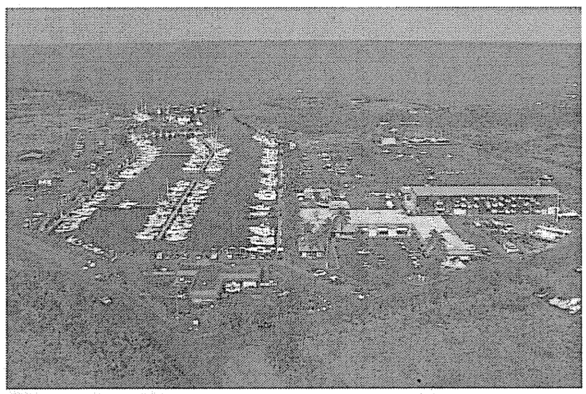


Figure 2: Proposed basin expansion with color-coded dredged depths (pink: -13'; blue: -10'; orange: -8ft, all to MLW).



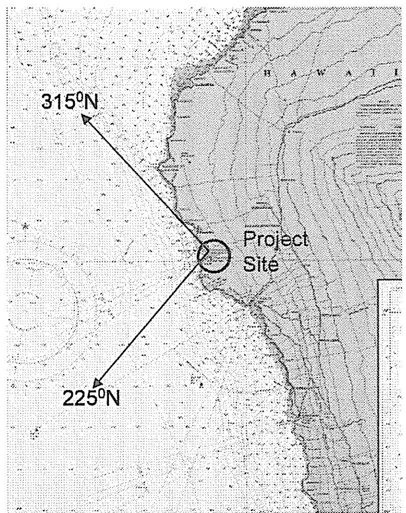


Figure 1: Project location
Right: western shoreline of the Hawaiian island showing the wave exposure window (from Chart 19327).
Left: an aerial of the existing basin with boat slips.

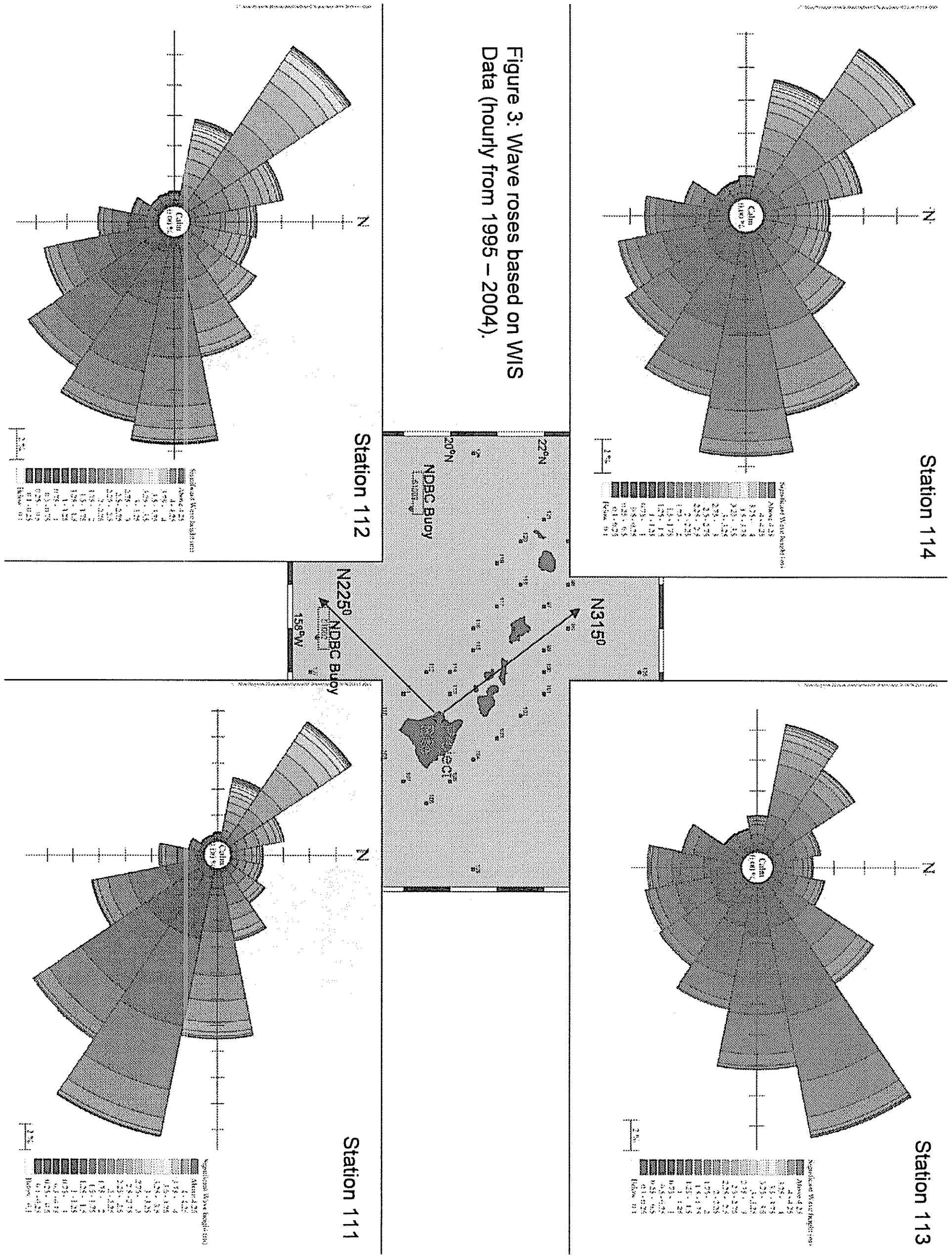


Figure 3: Wave roses based on WIS Data (hourly from 1995 – 2004).

1995-2004 PAC WIS STATION: 114 LAT: 20.00 N, LON:-157.00 W, DEPTH:4390 M
PERCENT OCCURANCE OF WAVE HEIGHT AND PEAK PERIOD FOR ALL DIRECTIONS

All Directions

Hmo (m)	Tp (sec) 3.0-3.9	4.0-4.9	5.0-5.9	6.0-6.9	7.0-7.9	8.0-8.9	9.0-9.9	10.0-10.9	11.0-13.9	14.0-LONGER	CASES	PERCENT OF TOTAL
0.00 - 0.49	.	0.02	.	0.01	.	.	.	.	.	.	20	0.02
0.50 - 0.99	0.05	0.06	.	.	0.09	0.32	0.86	2.08	6.07	2.05	10149	11.58
1.00 - 1.49	0.02	2.08	0.08	.	0.08	0.50	1.59	5.09	27.57	12.41	43313	49.41
1.50 - 1.99	.	0.62	1.59	0.01	0.01	0.07	0.16	0.81	13.74	8.72	22553	25.73
2.00 - 2.49	.	.	0.56	0.20	0.01	0.03	0.03	0.08	3.36	4.81	7964	9.08
2.50 - 2.99	.	.	0.01	0.09	0.01	0.01	0.00	0.03	0.69	2.07	2551	2.91
3.00 - 3.49	.	.	.	0.01	.	0.00	.	0.00	0.12	0.67	709	0.81
3.50 - 3.99	.	.	.	0.00	0.01	0.01	.	.	0.02	0.26	259	0.30
4.00 - 4.49	.	.	.	.	.	.	.	.	0.01	0.12	110	0.13
4.50 - 4.99	.	.	.	.	.	.	.	.	0.00	0.02	20	0.02
5.00 - GREATER	.	.	.	.	.	.	.	.	.	0.02	14	0.02
CASES THIS BAND	61	2430	1955	280	180	840	2324	7080	45216	27296	87662	100.00

1995-2004 PAC WIS STATION: 114 LAT: 20.00 N, LON:-157.00 W, DEPTH:4390 M
PERCENT OCCURRENCES OF WAVE HEIGHT AND PEAK PERIOD FOR DIRECTION BAND(281.25 - 303.74) 292.5 DEGREES

292.5⁰N

Hmo (m)	Tp (sec) 3.0-3.9	4.0-4.9	5.0-5.9	6.0-6.9	7.0-7.9	8.0-8.9	9.0-9.9	10.0-10.9	11.0-13.9	14.0-LONGER	CASES	PERCENT OF TOTAL
0.00 - 0.49	.	.	.	.	.	.	.	.	.	.	0	0.00
0.50 - 0.99	.	.	.	.	.	.	0.03	0.03	0.10	0.00	147	0.17
1.00 - 1.49	.	.	.	.	.	.	0.06	0.20	1.37	0.15	1553	1.77
1.50 - 1.99	.	.	.	.	.	.	0.00	0.03	1.93	0.53	2178	2.48
2.00 - 2.49	.	.	.	.	.	.	0.00	0.00	0.84	0.74	1309	1.50
2.50 - 2.99	.	.	.	.	.	.	.	.	0.20	0.57	675	0.77
3.00 - 3.49	.	.	.	.	.	.	.	.	0.05	0.29	296	0.34
3.50 - 3.99	.	.	.	.	.	.	.	.	0.02	0.14	142	0.16
4.00 - 4.49	.	.	.	.	.	.	.	.	0.01	0.09	89	0.10
4.50 - 4.99	.	.	.	.	.	.	.	.	0.00	0.02	20	0.02
5.00 - GREATER	.	.	.	.	.	.	.	.	.	0.02	14	0.02
CASES THIS BAND	0	0	0	0	0	0	80	225	3956	2242	6503	7.42
TOTAL CASES(ALL BANDS)											87662	

1995-2004 PAC WIS STATION: 114 LAT: 20.00 N, LON:-157.00 W, DEPTH:4390 M
PERCENT OCCURRENCES OF WAVE HEIGHT AND PEAK PERIOD FOR DIRECTION BAND(303.75 - 326.24) 315.0 DEGREES

315⁰N

Hmo (m)	Tp (sec) 3.0-3.9	4.0-4.9	5.0-5.9	6.0-6.9	7.0-7.9	8.0-8.9	9.0-9.9	10.0-10.9	11.0-13.9	14.0-LONGER	CASES	PERCENT OF TOTAL
0.00 - 0.49	.	.	.	.	.	.	.	.	.	.	0	0.00
0.50 - 0.99	.	.	.	.	.	.	0.00	0.11	0.07	0.02	175	0.20
1.00 - 1.49	.	.	.	.	.	0.00	0.03	0.25	1.79	0.49	2243	2.56
1.50 - 1.99	.	.	.	.	.	.	.	0.03	2.30	1.59	3446	3.93
2.00 - 2.49	.	.	.	0.00	.	.	.	.	0.88	1.94	2476	2.82
2.50 - 2.99	.	.	.	.	0.00	0.00	0.00	0.00	0.21	1.01	1079	1.23
3.00 - 3.49	.	.	.	.	.	.	.	0.00	0.02	0.28	266	0.31
3.50 - 3.99	.	.	.	.	.	.	.	.	0.00	0.09	79	0.09
4.00 - 4.49	.	.	.	.	.	.	.	.	.	0.02	21	0.02
4.50 - 4.99	.	.	.	.	.	.	.	.	.	.	0	0.00
5.00 - GREATER	.	.	.	.	.	.	.	.	.	.	0	0.00
CASES THIS BAND	0	0	0	2	4	2	35	345	4620	4779	9787	11.16
TOTAL CASES(ALL BANDS)											87662	

1995-2004 PAC WIS STATION: 114 LAT: 20.00 N, LON:-157.00 W, DEPTH:4390 M
PERCENT OCCURRENCES OF WAVE HEIGHT AND PEAK PERIOD FOR DIRECTION BAND(326.25 - 348.74) 337.5 DEGREES

337.5⁰N

Hmo (m)	Tp (sec) 3.0-3.9	4.0-4.9	5.0-5.9	6.0-6.9	7.0-7.9	8.0-8.9	9.0-9.9	10.0-10.9	11.0-13.9	14.0-LONGER	CASES	PERCENT OF TOTAL
0.00 - 0.49	.	.	.	.	.	.	.	.	.	.	0	0.00
0.50 - 0.99	.	.	.	.	.	.	0.02	0.08	0.14	0.01	209	0.24
1.00 - 1.49	.	.	.	.	.	.	0.00	0.24	1.87	0.43	2225	2.54
1.50 - 1.99	.	.	.	.	.	.	.	0.02	1.28	0.88	1907	2.18
2.00 - 2.49	.	.	.	.	.	.	.	.	0.30	0.57	766	0.87
2.50 - 2.99	.	.	.	.	.	.	.	.	0.03	0.18	184	0.21
3.00 - 3.49	.	.	.	.	.	.	.	.	.	0.03	27	0.03
3.50 - 3.99	.	.	.	.	.	.	.	.	.	0.01	8	0.01
4.00 - 4.49	.	.	.	.	.	.	.	.	.	.	0	0.00
4.50 - 4.99	.	.	.	.	.	.	.	.	.	.	0	0.00
5.00 - GREATER	.	.	.	.	.	.	.	.	.	.	0	0.00
CASES THIS BAND	0	0	0	0	0	0	17	293	3164	1852	5326	6.08
TOTAL CASES(ALL BANDS)											87662	

Figure 4: Wave height – wave period – frequency tables for WIS Station 114. The top is for all directions while the bottom three are for the three dominant directions in the northeast sector.

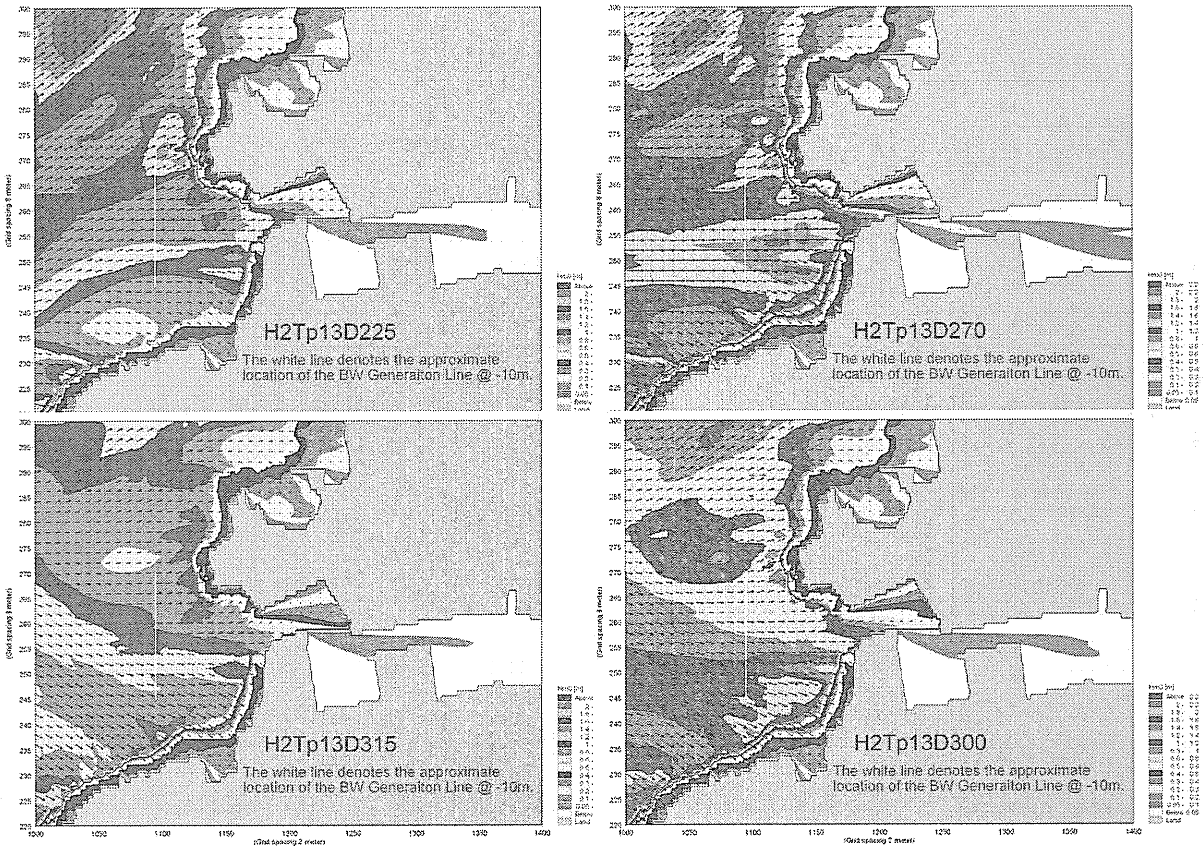


Figure 6: Wave height contours and directional vectors from NSW runs (H_{mo} = 2m, T_p = 13s at MSL): From top left going clockwise: 225⁰N, 270⁰N, 300⁰N, and 315⁰N.

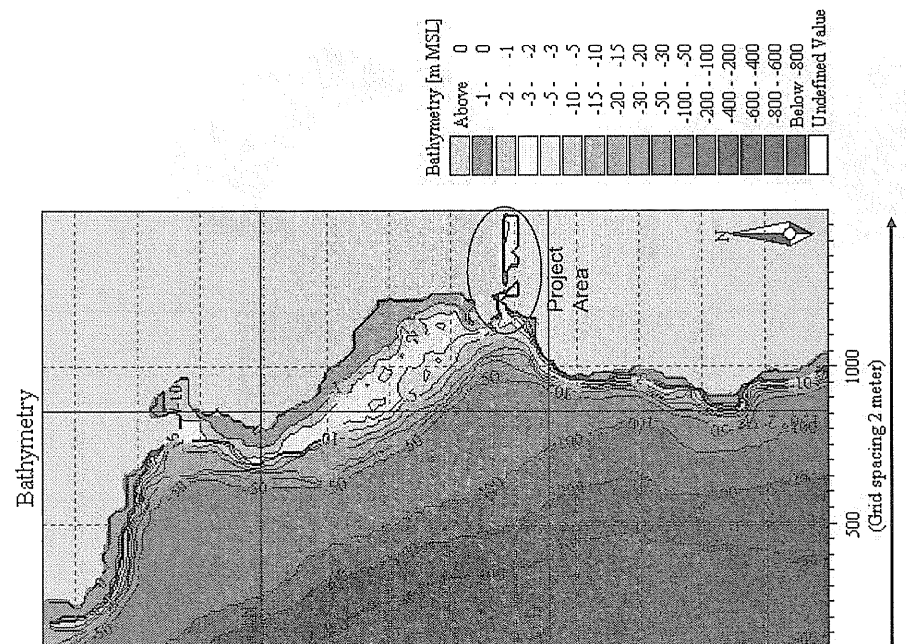


Figure 5: Model domain for NSW runs.

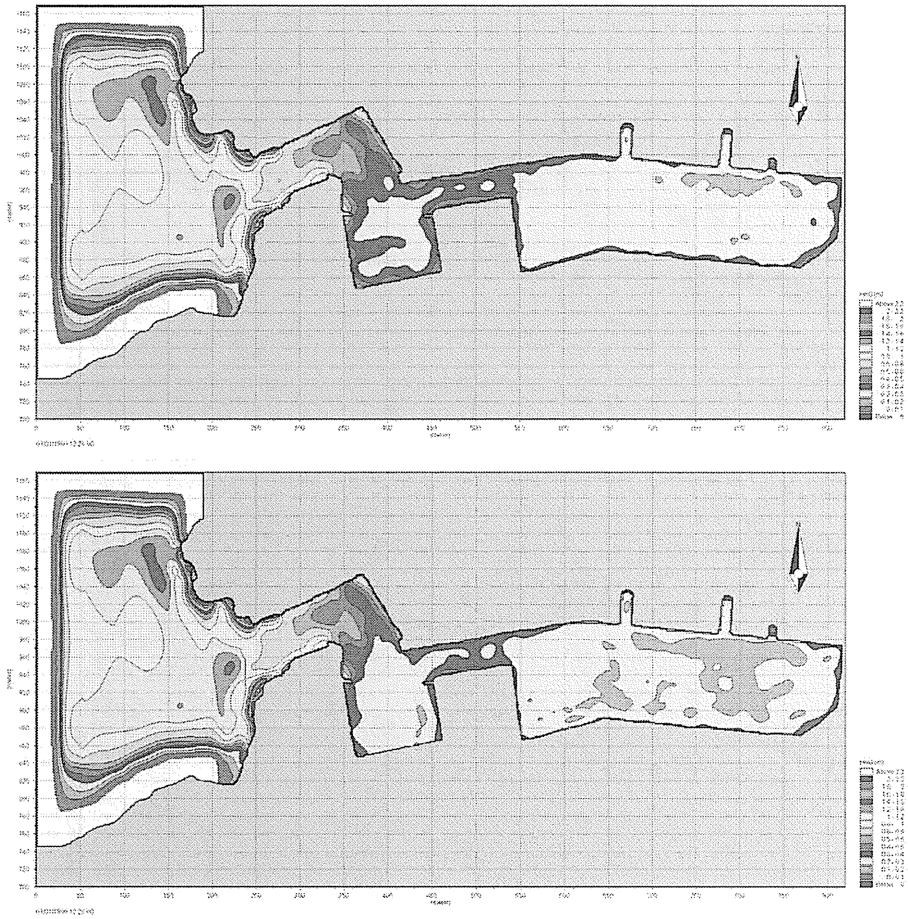


Figure 8: Comparison of wave height distribution (H_{mo} = 1m): Top: Existing basin; Bottom: Proposed Expansion

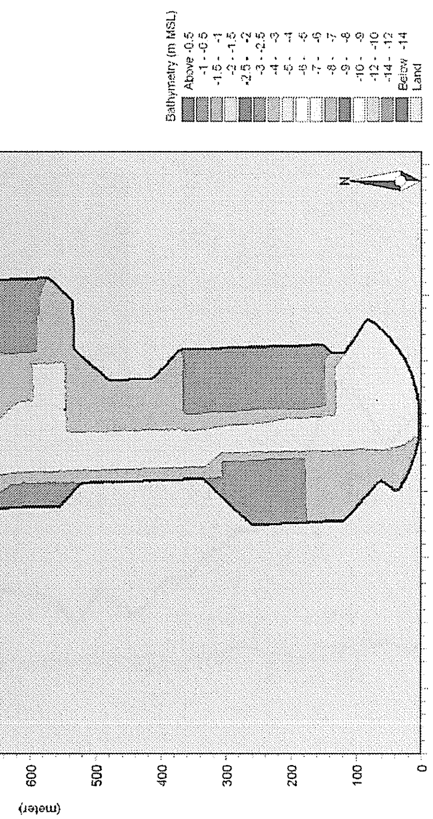


Figure 7: Model domain for BW runs.

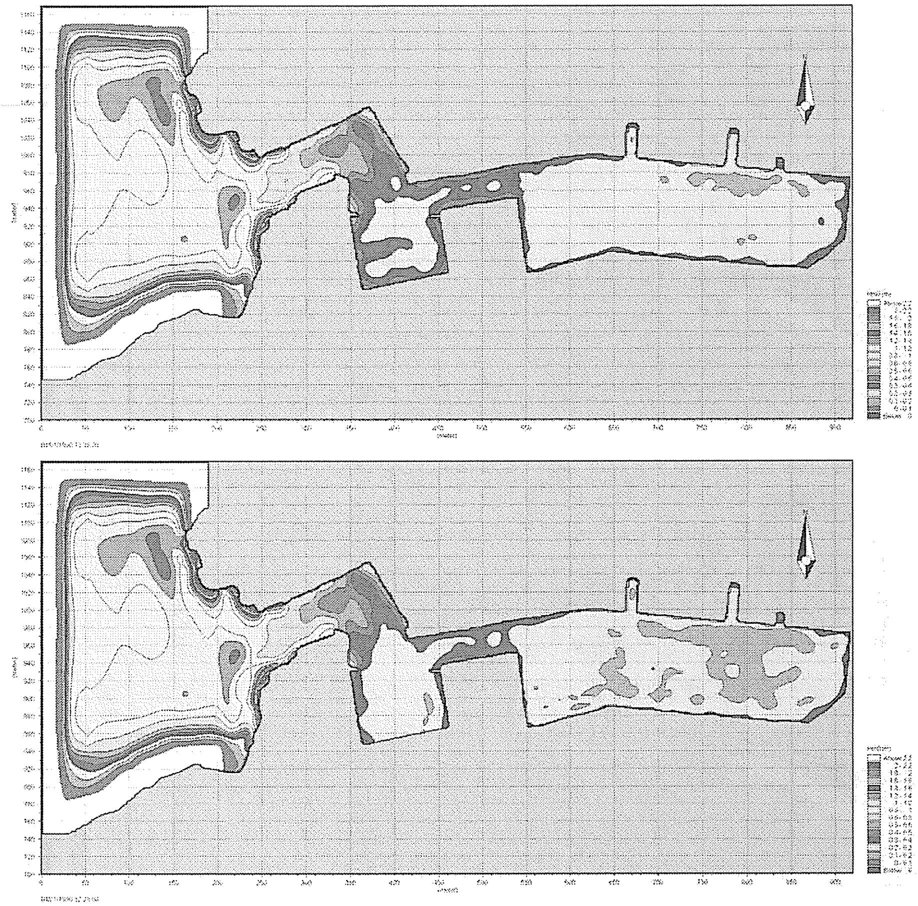


Figure 10: Comparison of wave height distribution (H_{mo} = 2m): Top: Existing basin; Bottom: Proposed expansion

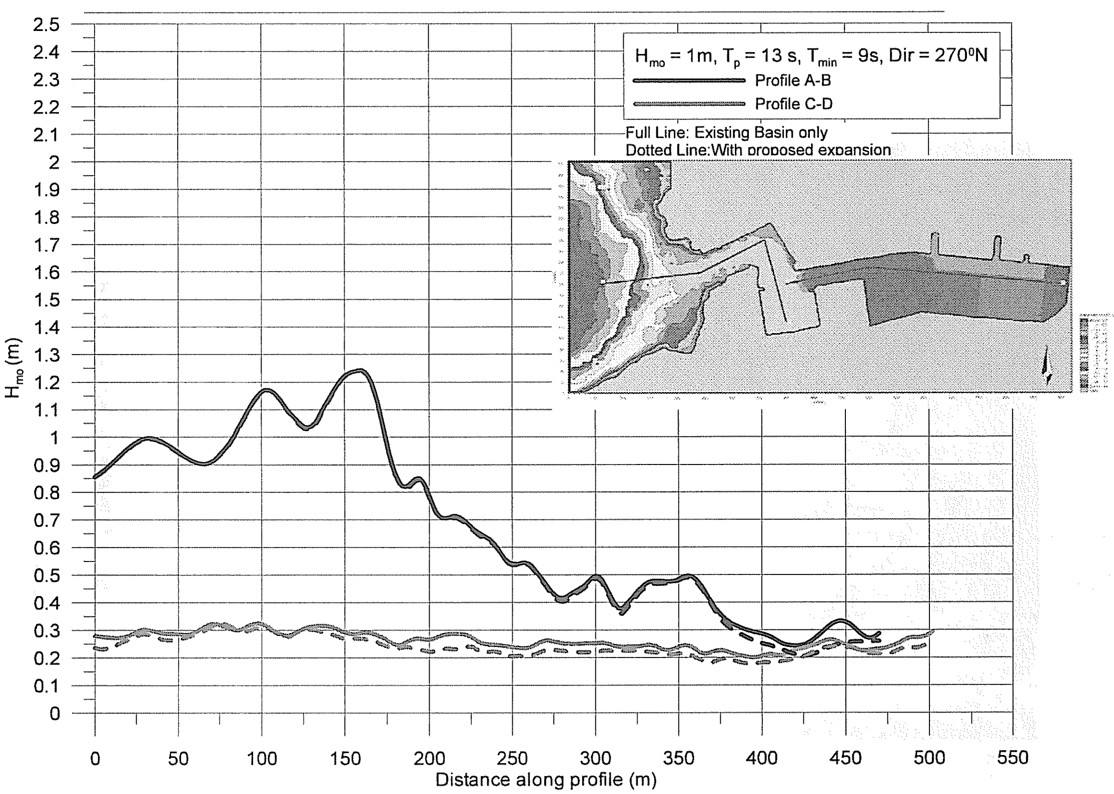
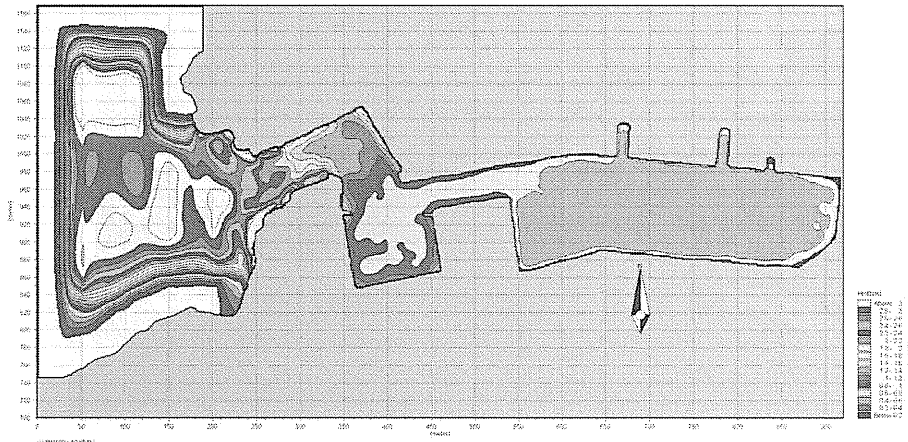


Figure 9: Wave height comparison along profiles in the existing basin



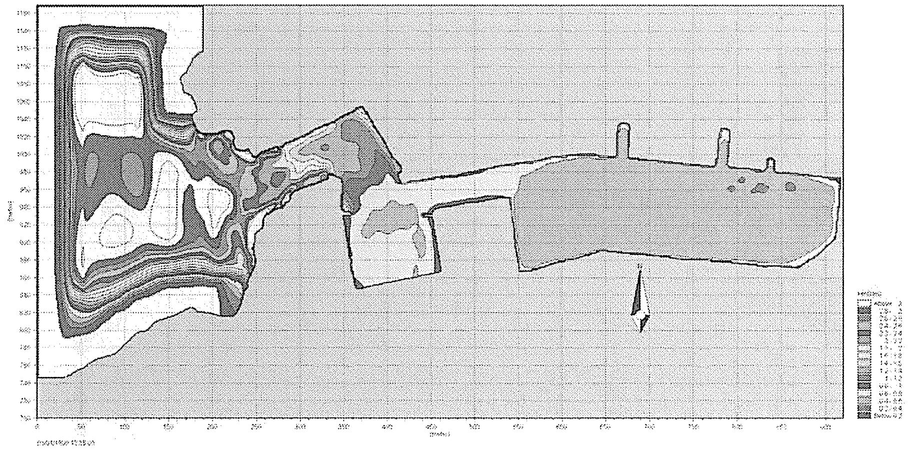


Figure 12: Comparison of wave height distribution (H_{mo} = 3m): Top: Existing basin; Bottom: Proposed Expansion

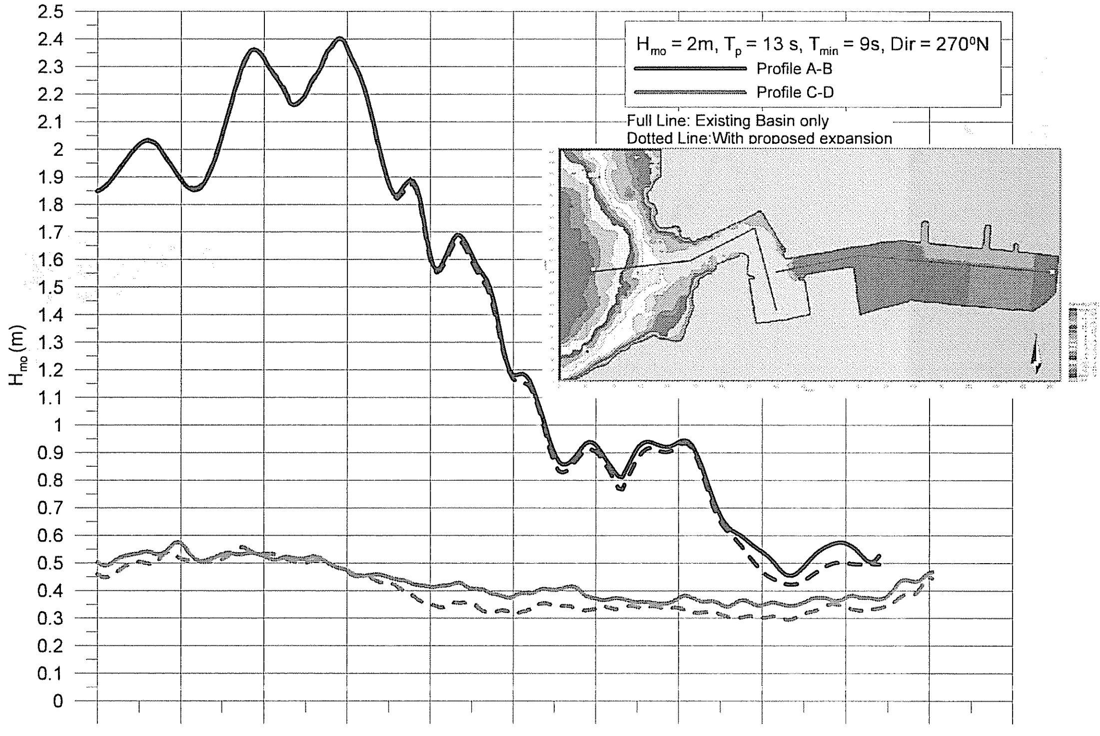


Figure 11: Wave height comparison along profiles in the existing basin.

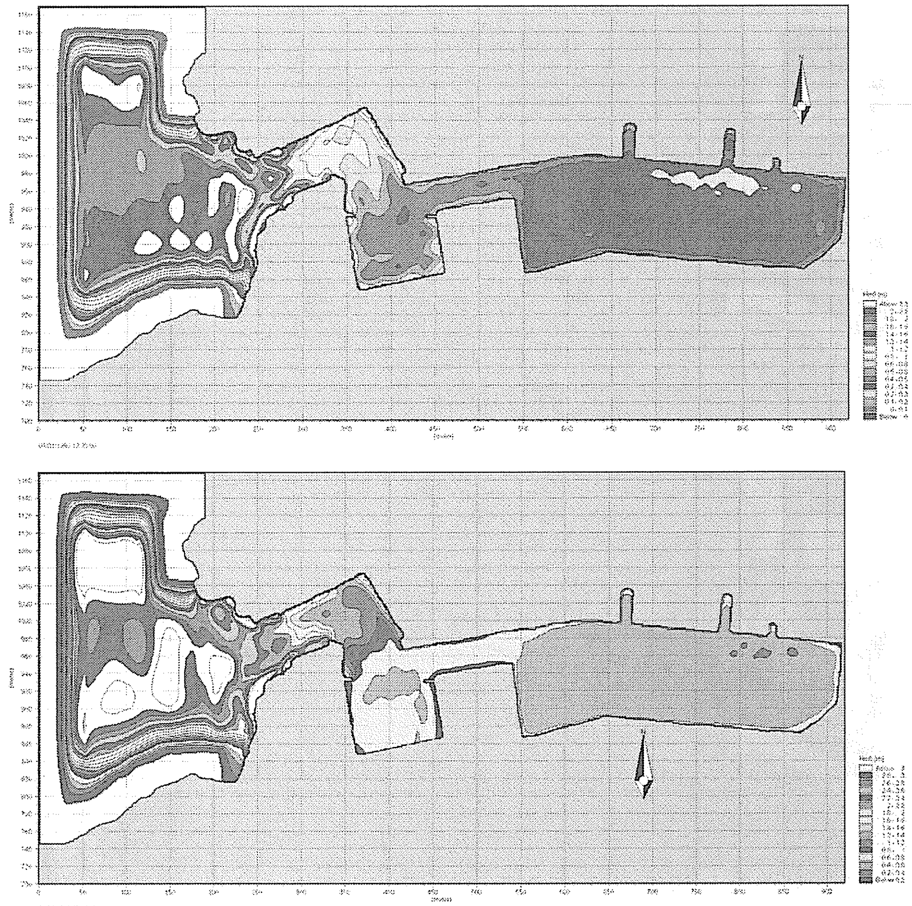


Figure 14: Comparison of wave height distribution (H_{mo} = 2m, T_p=9s): Top: Existing basin; Bottom: Proposed Expansion

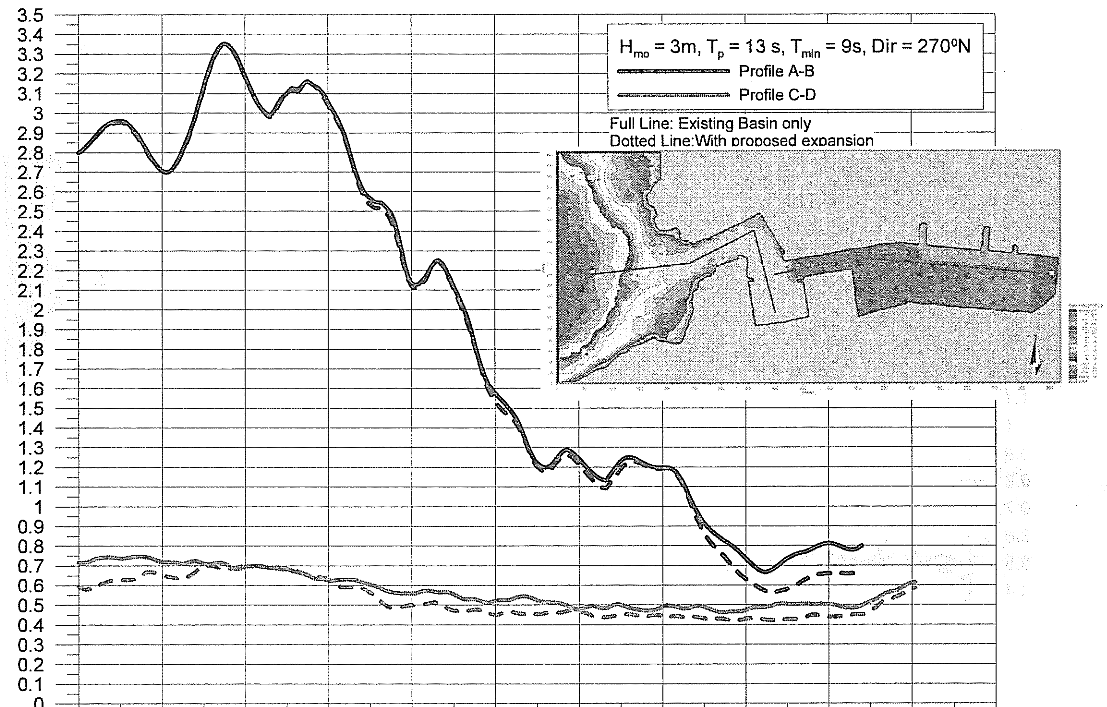


Figure 13: Wave height comparison along profiles in the existing basin.

Figure 16: Wave height distribution within the proposed basin expansion. (H_{mo} = 1m, T_p = 13s, Direction = 270^{0}N)

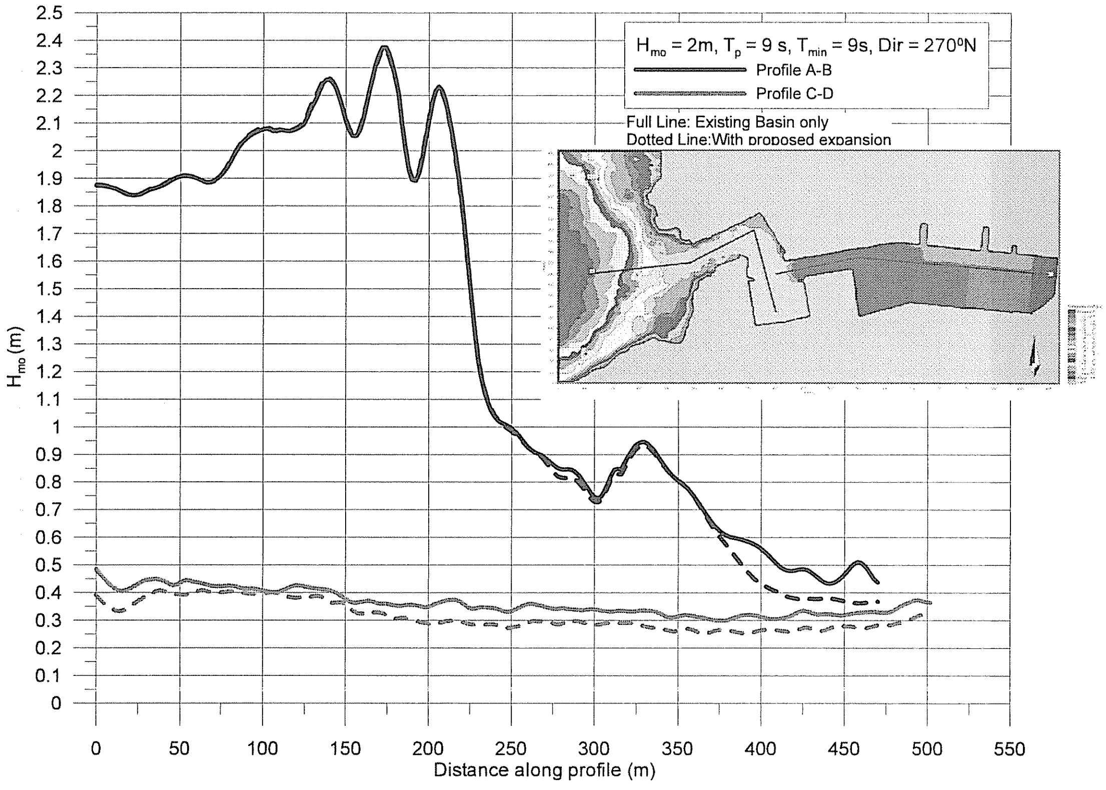


Figure 15: Wave height comparison along profiles in the existing basin.

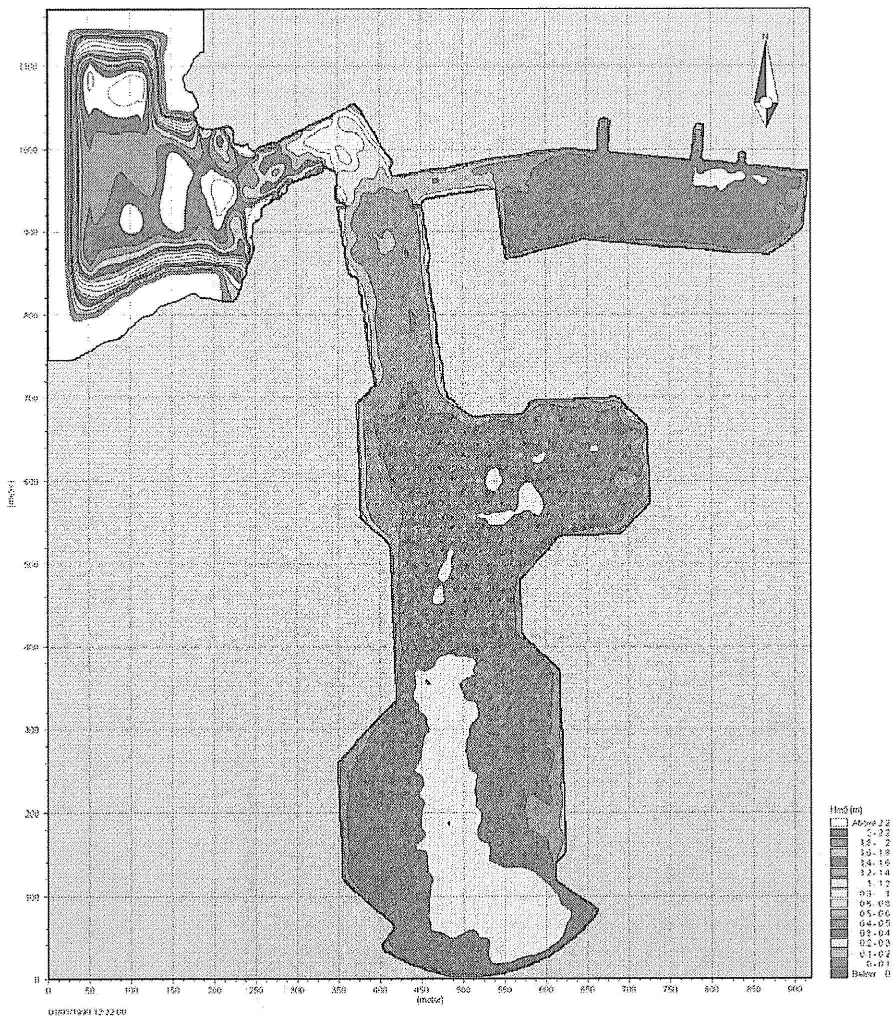


Figure 17: Wave height distribution within the proposed basin expansion. (H_{mo} = 2m, T_p = 13s, Direction = 270^0N)

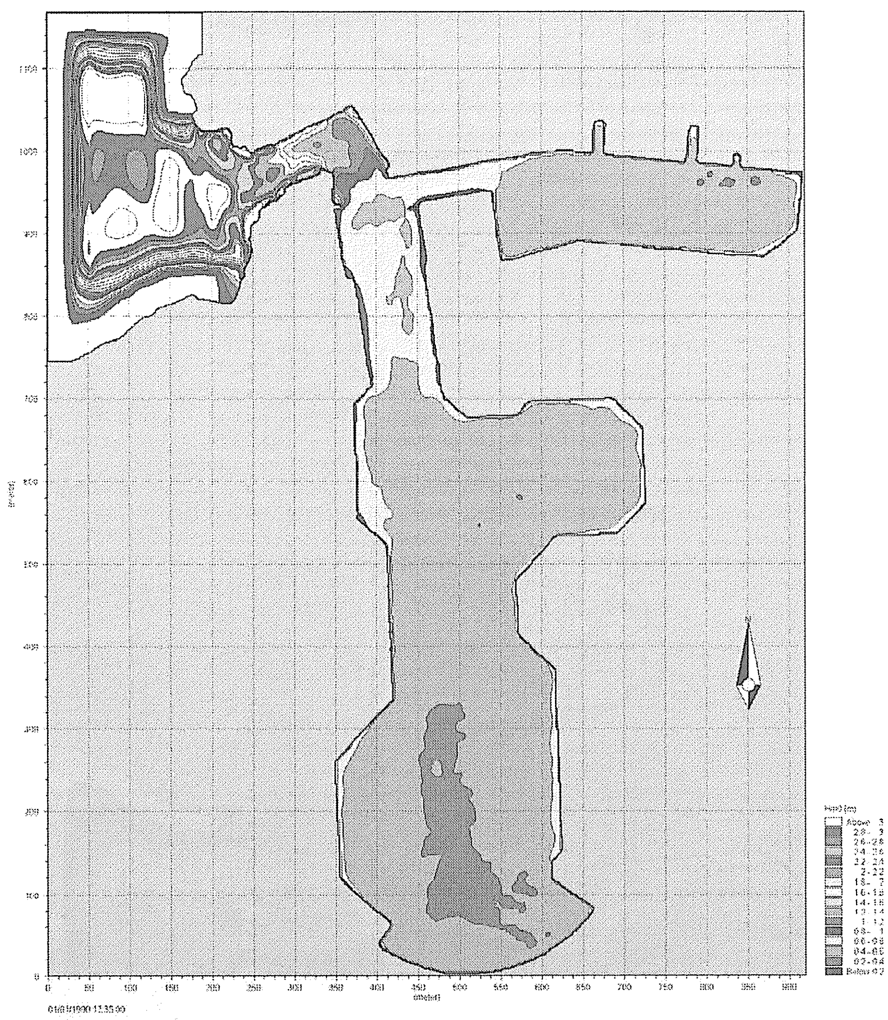


Figure 18: Wave height distribution within the proposed basin expansion. (H_{mo} = 3m, T_p = 13s, Direction = 270^0N). Note that the legend here is different from that in Figs. 16, 17 and 19.

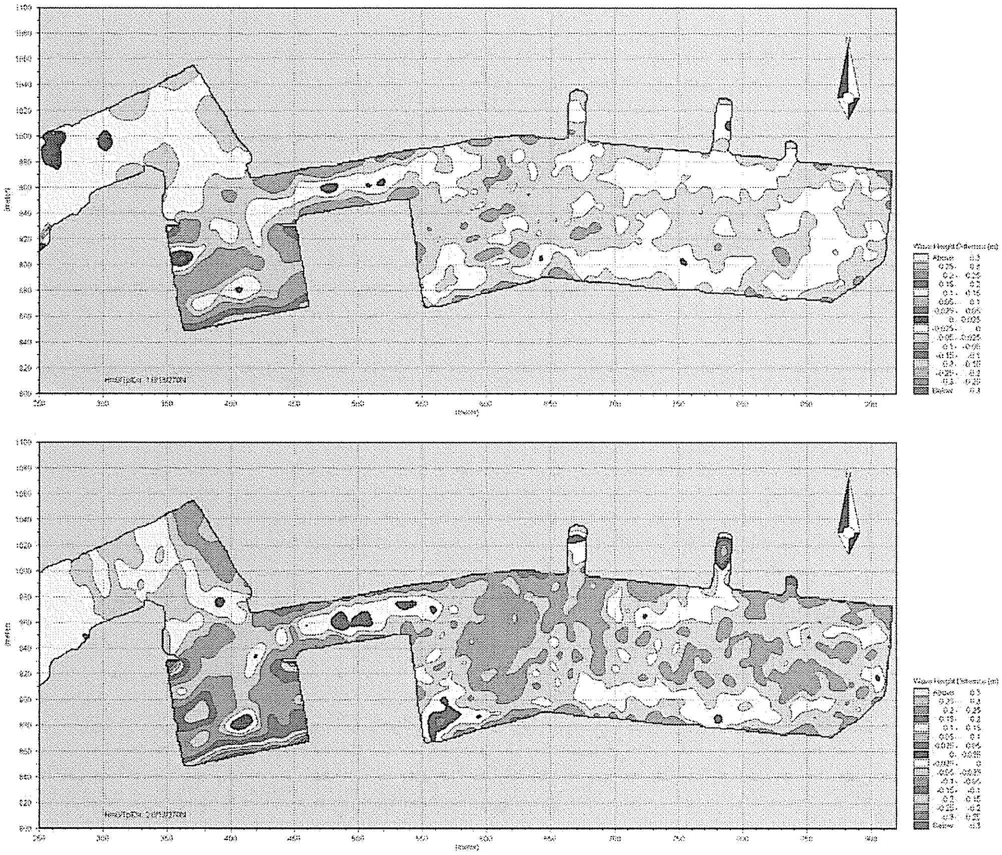


Figure 20: Wave height difference maps: Top: H_{mo} = 1m, T_p = 13s; Bottom: H_{mo} = 2m, T_p = 13s.
Note that the colors blue/green represent wave height increase and yellow/red/brown, wave height decrease.

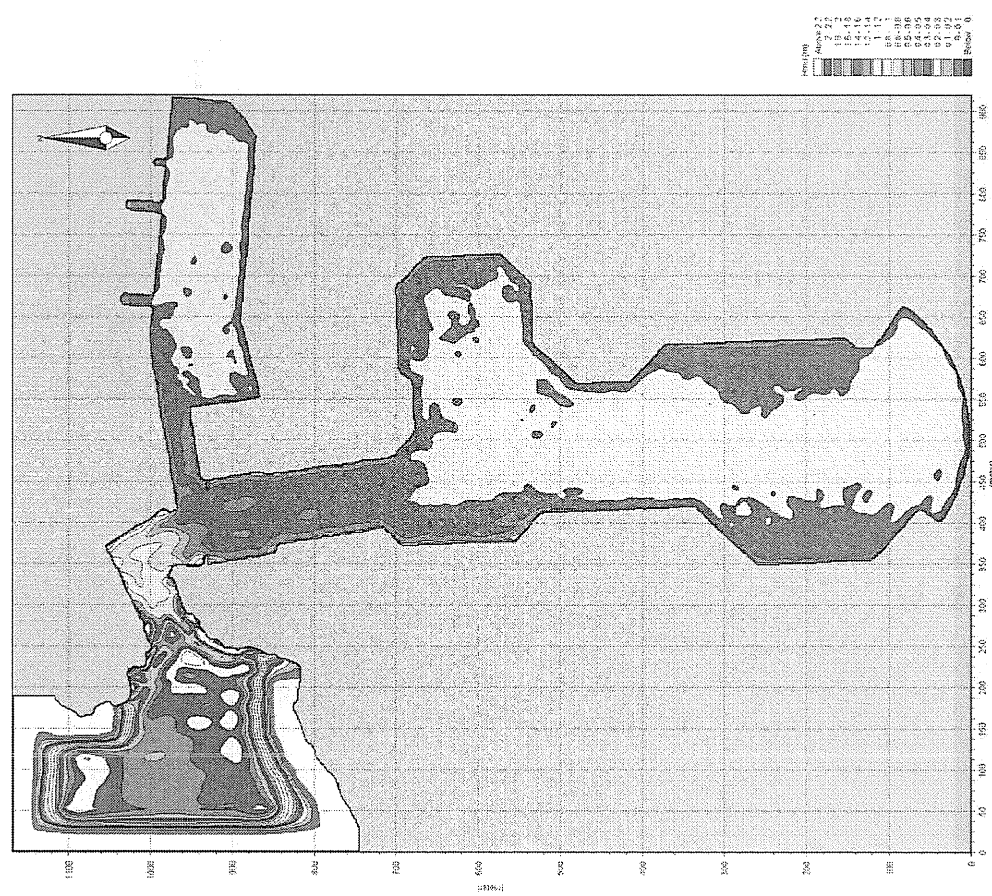


Fig. 19: Wave height distribution within the proposed basin expansion.
(H_{mo} = 2m, T_p = 9s, Direction = 270^0N).

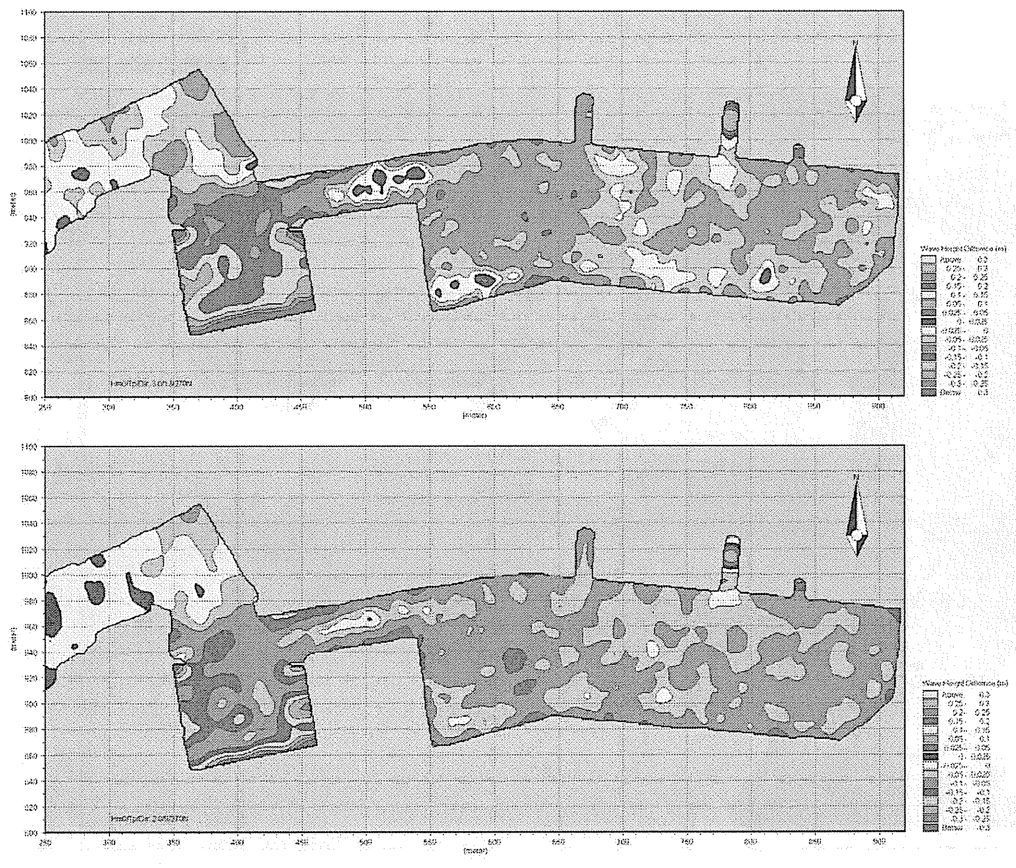


Figure 21: Wave height difference maps: Top: H_{mo} = 3m, T_p = 13s; Bottom: H_{mo} = 2m, T_p = 9s.
Note that the colors blue/green represent wave height increase and yellow/red/brown, wave height decrease.

Appendix K

Cooling Water Intake Analysis

By Oceanit

Cooling Water Intake Analysis
For Kona Kai Ola Development
Kona, Hawaii

Literature Review and Report For

Jacoby Development, Inc.

By

Oceanit Laboratories, Inc.

November 2006

Kona Kai Ola Development: Cooling Water Intake Analysis

Background

Kona Kai Ola development plans to use deep ocean cold water for providing cooling and air conditioning to the planned residential and commercial facilities. Water, sufficiently cold for his purpose, is available relatively close to the shoreline at about 3000 feet of water depth. This report analyzes the availability, water quality and probable impacts of disposal after use.

Cold Water Requirement

The project plans to utilize an average of 7,500 gallons per minute (GPM) of water at 40°F (4.5° C) for cooling and air conditioning purposes. The water might heat up by about 2° F during the pumping from the deep ocean to the heat exchangers at the cooling site. The amount of heating depends on the diameter of the pipe and the resident time of the water in the pipe during transit. The used water will still be cooler than surface waters high in nutrients and silicates and low in dissolved oxygen concentration. This water is not suitable for surface disposal, and would most likely be disposed of in an injection well.

Cold Water Availability

Measurement of temperature profiles at the site show that the water temperature reaches 41° F (5° C) at water depth between 29,00 feet to 3,300 feet. At Honokohau, the 3,000 feet depth contour lies approximately 12,000 feet offshore. Figure 1 and Figure 2 show the bathymetric details for the area. The bathymetric charts show that, a pipeline starting from the south of the Honokohau Harbor entrance, laid in approximately WSW direction to a distance of about 11,000 feet will reach the 3,000 feet depth, where the water temperature is about 40° F. The water, if pumped at 6 ft. per second (FPS) through a 24 inch diameter pipe would take about 30 minutes to reach the shoreline. At a lower flow velocity of, say, 3 FPS the pipe should be 32 inches diameter to accommodate the required flow. The pressure loss will be about 20 percent from the 24 inch pipe, but the water would take about an hour to reach the shoreline, possibly increasing the heat gain during transit.

At Keahole Point, a 18 inch diameter pipe with the intake at 2060 feet pumps 3,000 GPM from a distance of 6180 feet offshore, and a 40 inch diameter pipe transmits 13,400 GPM of water from a depth of 2210 feet from a distance of 6280 feet offshore. The water temperature at the onshore pump varies from 42.6° F to 44.3° F for the 40 inch pipe and from 44.5° F to 45.5° F for the 18 inch pipe.

Typical temperature profiles for the project site are shown in Figure 3.

Water Quality Evaluation

Natural Energy Laboratory of Hawaii Authority (NELHA) is located at Keahole Point about 2 miles north of the project site. Cold water from 3,000 feet depth is continuously pumped at this facility for research and commercial purposes. Insitu as well as existing data were reviewed to determine quality of water pumped form this depth. The available data were researched and verified for this purpose.

Temperature

The surface mixed layer in this area is 150 to 200 feet thick. Water temperature drops fast from 200 feet to about 1,200 feet depth. Thereafter, the temperature decrease is more gradual until it reaches about 41°F at about 3,000 feet. Although there is a seasonal variation of about 6.5°F at the surface, the temperature variation at 3,000 feet is less than one degree F.

Dissolved Oxygen

Dissolved oxygen concentration in deep ocean water varies from 1.0 to 1.7 mg/l compared to 6.7 mg/l for surface water. The deep ocean water is very anoxic and cannot support the nearshore ecology. Discharge of used water without oxygenation to the nearshore area will have major impacts to the nearshore ecology.

Nutrients

Nutrients considered for this evaluation are nitrogen and phosphorus. Concentration of total dissolved Nitrogen (TDN) varies from 43.1 micromoles to 46.0 micromoles for deep water as compared to 5.2 micromoles for surface water. Total dissolved phosphorus (TDP) concentration in deep ocean water varies from 3.1 micromoles to 3.56 micromoles compare to 0.37 micromoles for surface water. Both TDN and TDP show a ratio of 8 to 10 between deep and surface water.

Dissolved Nitrogen and Phosphorus contribute to the productivity in water media in the presence of sun light. Discharge of used deep ocean water without reducing the nutrient concentrations would cause significant impacts to water clarity and nearshore benthic resources.

Silicates mainly come from diatom skeletons that fall through the water column. The silica concentration in deep water varies from 100 to 109 micromoles, compared to 5.7 micromoles at the surface. This might not produce significant ecological impacts at the surface. However, the high silica concentration might increase rate of biofouling in the heat exchangers.

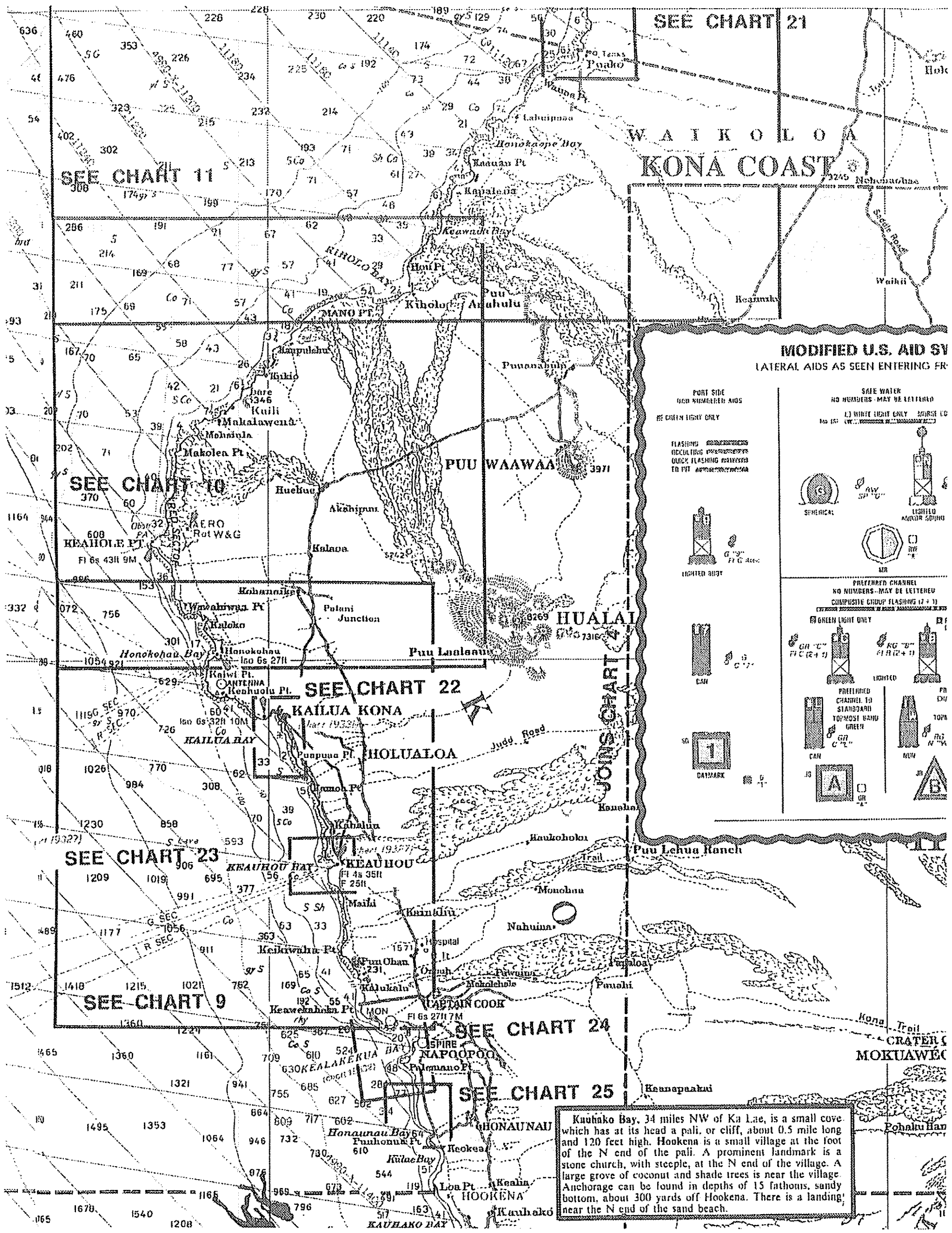
pH determines the degree of acidity in the water. Deep ocean water has a low pH mainly because of the carbon dioxide produces from decay of organic matter that fall through the water column. The Ph in deep water varies from 7.59 to 7.65 compared to 8.3 for surface

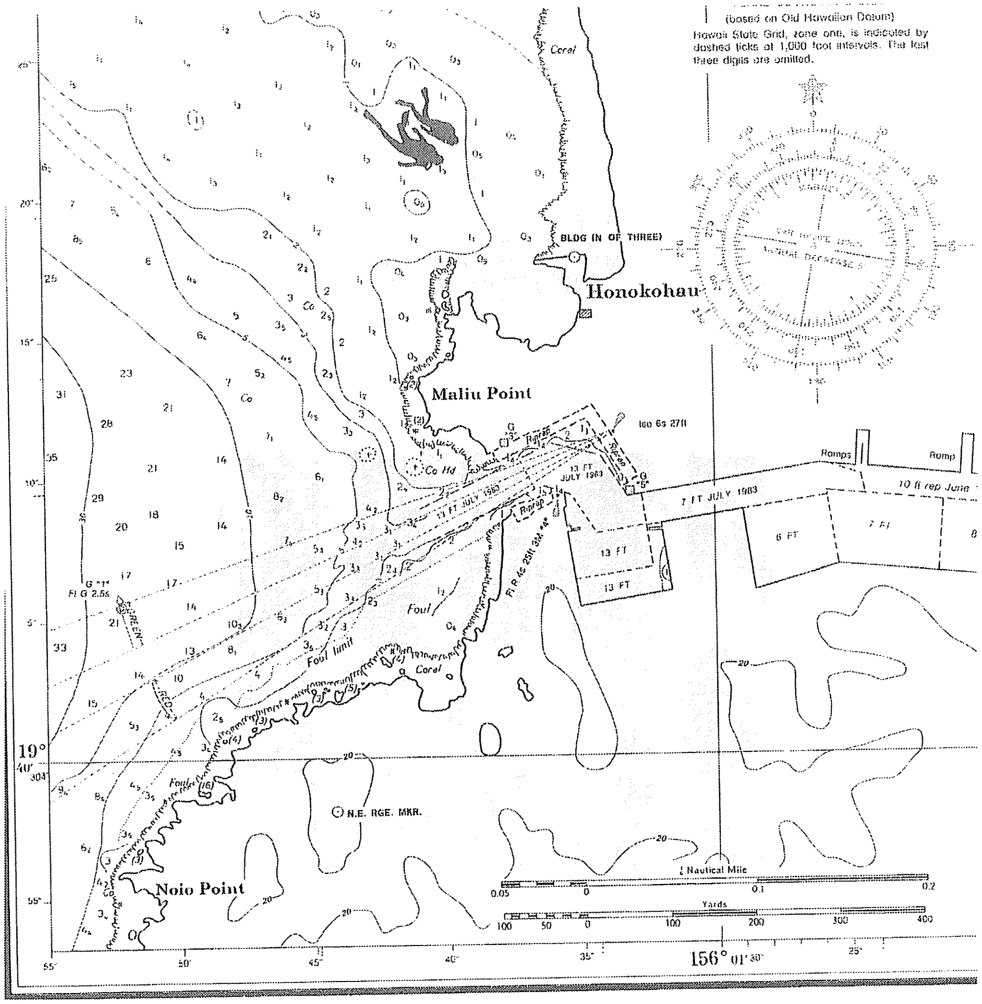
water. The increased acidity will impact the carbonate equilibrium in the nearshore water, if discharges untreated.

The used deep ocean water effluent is high in nutrients, cold and has very low levels of pathogens. This makes it ideal for mariculture. Use of the this resource for mariculture before discharging into the environment will reduce the negative impacts and provide an economic value.

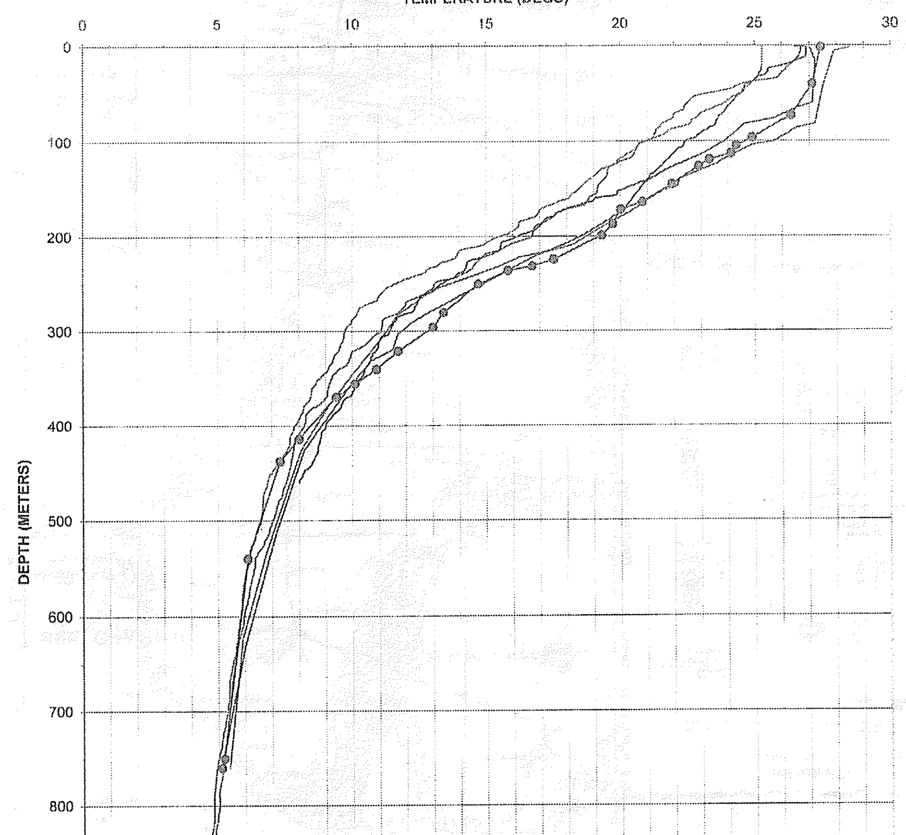
If the effluent was to be discharged through an injection well, the quality of effluent and the ocean water quality profile will have to be considered in designing the effluent discharge depth in the injection well. At least, the density of the effluent should match the sea water density at injection level to avoid creation of local vertical mixing cells.

Typical water quality profiles in the project area are shown in Figure 4.


SEE CHART 21
SEE CHART 11
SEE CHART 10
SEE CHART 22
SEE CHART 23
SEE CHART 9
SEE CHART 24
SEE CHART 25
JOINS CHART
W A I K O L O A
KONA COAST
PUU WAAWAA
HUALAI
KAILUA KONA
HOLUALOA
KEAUHOU
CAPTAIN COOK
NAPOOPOO
HOOKENA
MOKUAWEO
MODIFIED U.S. AID SY
LATERAL AIDS AS SEEN ENTERING FR
Kauhako Bay, 34 miles NW of Ka Lae, is a small cove which has at its head a pali, or cliff, about 0.5 mile long and 120 feet high. Hookena is a small village at the foot of the N end of the pali. A prominent landmark is a stone church, with steeple, at the N end of the village. A large grove of coconut and shade trees is near the village. Anchorage can be found in depths of 15 fathoms, sandy bottom, about 300 yards off Hookena. There is a landing near the N end of the sand beach.


(based on Old Hawaiian Datum)
Hawaii State Grid, zone one, is indicated by dashed ticks at 1,000 foot intervals. The last three digits are omitted.
Honokohau
BLDG (N OF THREE)
Maliu Point
Noio Point
N.E. RGE. MKR.
Nautical Mile
Yards
156° 01' 30"

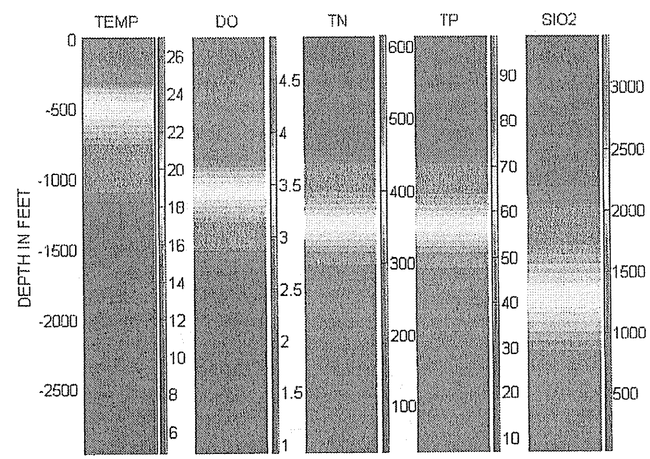
Honokohau - Historic XBT Data



CAST #	DATE UTC	VESSEL NAME	INST.	LAT DEC. DEG.	LONG DEC. DEG	CAST DEPTH M	BOTTOM DEPTH M	INSTRUMENT TYPE	INSTRUMENT MODEL	CAST WOD #
1	8/25/2000	MCARTHUR	US	19.77	-156.16	760	3000	XBT	SIPPICAN MK-12	9587401
2	10/26/2002	MCARTHUR	US	19.79	-156.17	760	2500	XBT	SIPPICAN MK-12	9855904
3	1/26/1996	BRISBANE STAR		19.75	-156.20	835	n/a	XBT	SIPPICAN MK-12	9345123
4	10/4/1993	CALIF. STAR	SCRIPPS	20.00	-156.26	850	n/a	XBT	SIPPICAN MK-12	4097690
5	7/18/2004	PARRAMATA	AUS. NAVY	20.14	-156.40	460	n/a	XBT	SIPPICAN MK-12	10441479
6	10/26/2002	MCARTHUR	US	19.67	-156.05	760	5530	XBT	SIPPICAN MK-12	9855897

SOURCE: World Ocean Database 2005, via National Oceanographic Data Center (www.nodc.noaa.gov)

VARIATION OF SELECTED WATER QUALITY PARAMETERS WITH DEPTH



DEPTH:	FEET
DISSOLVED OXYGEN:	MILLIGRAMS PER LITER
TOTAL NITROGEN:	MICROGRAMS PER LITER
TOTAL PHOSPHORUS:	MICROGRAMS PER LITER
SILICA:	MICROGRAMS PER LITER

Appendix L-1

Cultural Impact Assessment 2006

By Taupōuri Tangarō, Ph.D.,
Kuʻulei Higashi Kanahele,
William Māhealani Pai

KONA KAI OLA PROJECT
Kealakehe and Keahuolū Ahupua'a
Hawai'i Island
Cultural Impact Assessment

Prepared for:
Oceanit Laboratories, Inc.
Fort Street Mall, Suite 600
Honolulu, Hawai'i 96813

Prepared by:
Taupōuri Tangarō, Ph.D.
Ku'ulei Higashi Kanahele
William Māhealani Pai
1114 Auwae Rd
Hilo, Hawai'i 96720-6914

CONTENTS

EXECUTIVE SUMMARY

Consultant is contracted by Oceanit to prepare a Cultural Impact Assessment (CIA) for the development of The Kona Kai Ola Project in the makai lands of Kealakehe on the Kona coast of the island of Hawai'i: 200 acres of land belonging to the Hawai'i Department of Home Lands; 290 acres of land belonging to the Hawai'i Department of Land and Natural Resources (DLNR), which is divided into multiple parcels including all or portions of TMK: 7-4-08:03, TMK: 7-4-8:71, and others. These lands are located within the Kealakehe ahupua'a in the judicial district of North Kona in the County of Hawai'i.[i]

CHAPTER ONE:
METHODOLOGY

The information provided in this study was extrapolated from the following:

- Review of maps
- Walking the sites
- Research historical documents
- Review Oceanit report drafts
- Oral interviews from Kepā Maly's He Wahi Mo'olelo 'Ohana No Kaloko Me Honokōhau Ma Kekaha O Nā Kona, A Collection of Family Traditions Describing Costumes, Practices, and Beliefs of the Families and Lands of Kaloko and Honokōhau, North Kona, Island of Hawai'i (2002)
- The CIA report by Pualani Kanaka'ole Kanahele entitled Kealakehe, Commercial/Industrial Park, North Kona, Island of Hawai'i (2001).

Research Of Historical Documents And Oral Histories

Salient contributions to this CIA are Wahi Pana Place Names of Hawai'i, Hawai'i's numerous kā'ao, or sacred myth documentations, the works by Mary Kawena Pukui. Wahi Pana, or Legend Place Names of Hawai'i, contains much information on the function and or historical account related to an area by the translation and interpretation of its name. Another arena gleaned for information related directly and or indirectly to the project site are Hawai'i's ancient kā'ao, or sacred myth documentations. Kā'ao are undiluted accounts of use and continued function of a particular place. The strength of incorporating myth is not in the literalization of the text, which is the case in most instances, but the decoding of the metaphoric language as they relate to living practices.

Mr. Kepā Maly's (2002) exhaustive work in collecting oral histories of the Kekaha area of North Kona and South Kohala has also provided a glimpse of living on or nearby the proposed project site. The invaluable recordings are human sinews that validate ancient methods of living in hereditary domiciles as well as the modification of lifestyle as introduced by modern living. These contributions of oral histories continue to inform and direct the ever evolving face of Kona. Brief bibliographies of contributors are found throughout the document in sidebars.

The voluminous works of Mary Kawena Pukui are also relied upon for its non-obscure truth in the life cycle of Hawai'i. Likewise, the continuing experiences of Kona fisher-person and cultural exponent Mr. William Māhealani Pai are invaluable to the report as well as to the experience. Māhealani brings into this CIA, to the degree possible, a Kona perspective, which differs greatly from, say, that of a fisherperson from Waiāhole, O'ahu. I could not enter into this arena without Mr. Pai's cultural anchor.

Review Of Oceanit EIA Report Drafts

This CIA also reflects components of Oceanit's EIA draft reports. Flora, avian, terrestrial mammalian species survey reports, in addition to the archaeological inventory survey of Keahuolū ahupua'a was perused for the details that will assist in the shaping of the project. Absent from the perusal are the Archaeological inventory of Kealakehe ahupua'a and the marine survey report draft, neither draft available at the time of this draft report.

The methods used in the preparation of this CIA are in compliance with the guidelines for assessing cultural impacts as adopted by the Environmental Council, State of Hawai'i, November 19, 1997.

CHAPTER TWO:
DESCRIPTION OF PROJECT AND INTRODUCTION TO PROJECT SITE

Introduction To Project

Consultant met with David Tarnas on March 29, 2006 in Waiākea, Hilo, Hawai'i for a formal introduction of CIA domain. Maps of project area along with a spiral bound report entitled Kona Kai Ola, Mālama I Ka 'Āina, Jacoby Vision were viewed and discussed. I signed the contract to prepare the CIA at this meeting. Mr. Tarnas encouraged that Mr. William Māhealani Pai be part of this CIA, as Mr. Pai is a longtime Kona resident, fisherperson, cultural practitioner and consultant, as well as having a good standing in the Kona communities. I too have a good professional and cultural relationship with Mr. Pai; therefore, I retained Mr. Pai as a co-researcher on this project. Ms. Ku'ulei Tracy Kanahele also served as co-researcher and editor to this project.

Project Visitation And Paeaea Ceremony

After many phone and email correspondences with both Māhealani Pai (cultural practitioner) and Ku'ulei Kanahele (Hawaiian research specialist) we three conducted a Paeaea, a ceremony on the proposed site of the project that introduces who we are to the living systems of Kealakehe, Keahuolū and their contiguous ahupua'a, as well as to the mountain tops of Maunakea, Maunaloa, Hualālai, inclusive of Ka Moana Nui A Kanaloa, the ocean. Living systems includes the Hawaiian pantheon and 'aumākua, inclusive of their respective kinolau (the flora, fauna, elemental, physical and spiritual, phenomena manifestation).

Paeaea is a fishing prayer chant requesting from the living systems "fish" or clues from the ocean of deeper consciousness we know as ancestral memories. This need to incorporate ancestral memories in producing a CIA is integral to the individual and collective process of the research team, for it is this connection that will give dimension to the information gleaned from the oral and printed histories, EIS draft reports, traditional living practices, and the ancient chant text that contain the most potent and undiluted information relating to place and spirit.

Following the Paeaea, the research team walked the shoreline of Kealakehe to Noio Point, after which we drove to Keahuolū's Hi'iakaikanoholae Point. Although it is obvious that full-time residency on these makai ahupua'a lands are absent, it was apparent to the na'au (innate sensory knowledge) of the research team that this land is still alive with liminal activity. This liminal activity is to be covered in the body of the report.

Kīpaepae – A Passage Into The Sacred

The kīpaepae is a large stepping stone placed at the entrance of ancient architecture to assist in the passage from the profane world into that of the sacred. The Ao Hawai'i, or Hawaiian consciousness, is a sacred reality, and to understand it, the transition into the sacred is required. Here the kīpaepae must be defined.

Kīpaepae are necessary in that living does not often require profound understanding and articulation of life and life cycles. This reality, even amongst the most ancient, is what prompted the use of stepping stones, a physical and visual reminder that one has to leave one space for the other, the dividing line is this foundation stone, the kīpaepae.

The permanent alteration of a land/space for the proposed project requires first an understanding of the Ao Hawai'i. I, therefore, provide you with a kīpaepae defined by

sacred documentation (myth), historical documentation, and current records of living so that any alteration to land, space, and spirit is an alteration not to be regretted.

Hawaiian Consciousness
A Product Of Primordial Darkness

Hawaiian consciousness is metaphored by light after its passage through primordial darkness. The birth of light is the birth of cerebral consciousness, of place, of spirit, and of a profound reality (not belief, but reality) that the native person is a human progeny of a given geography. To leave Hawai'i and venture into Kahiki (land and space beyond the Hawaiian horizon[ii]) is to venture outside of the Hawaiian consciousness; to return from Kahiki into the horizon of Hawai'i is to enter into the Hawaiian consciousness.

The quintessential Hawaiian document of the dawn of Hawaiian consciousness is the Kumulipo, a 2,000-line genealogical chant composed by Keaulumoku in 1700.[iii] This chant is said to have been chanted at the birth of Kalaninui'iamamao, son and heir of King Keawe (ca. 1691-1736), paramount chief of Hawai'i.

Kumulipo means "Dark Origins" and by Dark Origin, we speak of the converse of light/consciousness: we speak of the dark/unconsciousness - also known as ancestral memory. Whereas consciousness addresses the biographical mind- the mind that begins to acquires knowledge at the point of physical birth, the unconscious mind (ancestral memory) is the collective lived experiences of our remotest ancestor and her descendants encoded in the DNA that is passed on at conception. The Kumulipo celebrates this profound equilibrium that anchors the native person to her geography.

The Kumulipo documents that in the beginning the cosmos is encapsulated by a primordial darkness known as Pō. The Heavens then intercourse with earth and born from this union are:

1. Kumulipo (male) and Pō'ele (female), both denoting profound darkness. From this union are born corals and mollusks.
2. Pōuliuli (male) and Pōwehiwehi (female). From this union the fish are born.
3. Pō'ele'ele (male) and Pōhāhā (female). From this union winged creatures are born.
4. Pōpanopano (male) and Pōlalowehi (female). This union engenders amphibians.
5. Pōkinikini (male) and Pōhe'enalumamao (female) engenders humans and light (ibid. p. 4-6)

The sequence of birth ordered by the Kumulipo enumerates the births of every living organism in the biosphere of Hawai'i. In the second period of creation, after enumerating the sequence of fish, the chant begins to address companion counterparts of marine life and terrestrial life. These simultaneous accountings for sea and land entities speak to the simultaneous development of both ancestral mind (sea life) and conscious mind (terrestrial life) of the native person. Native Hawaiian consciousness is best understood in the term of profound equilibrium, an exquisite and delicate balance of the ancient mind and the modern mind, the synchronization of the two spheres that must thrust into the world of evolution the decisions that will continue to resonate positively throughout the ages.

Before this chant entered the public domain, it belonged to a specific aristocratic family. This chant spoke to the profound equilibrium of a line of chiefs and a maka'ainana people, who, by association to the paramount chief, are sustained by this profound equilibrium of inseparability from the Hawaiian cosmos. Yes, Ao Hawai'i, Hawaiian consciousness of place and spirit is a human product after a long birth of primordial parentages, which, in their primordial unions, produced the land base from which the Hawaiian would draw the paradigm for spirit engenderment.

Alas, we have, in theory, experienced the origin of native consciousness. Now, how it relates to the project site is to follow.

Hawai'i The Firstborn

Hawai'i cosmogony places Hawai'i Island as the firstborn, the child on whom the island family will depend upon for spiritual and physical health. The 'aha'aina māwaewae, or feast for clearing the path, is conducted once, and this is within the 24 hours after the birth of the firstborn child. The māwaewae dedicates the firstborn as the island vehicle of the family archipelago onto which the spiritual and physical health of the entire family, living and dead, would ride upon.[iv] And as there exist no distinction of physical land and its human inhabitants (both products of primordial Pō, Darkness), this paradigm of rites of passage has its microcosmic manifest in the human habitants of this land. It is this paradigm that will give direction to understanding the slant of this CIA as it relates to the project site as a conduit for the perpetuity of land and spirit, life and living. Following is a traditional creation chant:

'O Wākea Kahiko Luamea	Wākea of the ancient Celestial vault
'O Papahānaumoku ka wahine	[Mates] with the female Papa-birther-of-islands
Hānau Kahiki Kū,	Established is the eastern horizon- consciousness
Hānau Kahiki Moe,	...the western horizon - ancestral return
Hānau Ke'āpapanu'u,	...the birth of gods at the Zenith - priest
Hānau Ke'āpapalani,	...gods at the highest station - paramount chief
Hānau Hawai'i	...Hawai'i is borne into consciousness
He keiki makahiapo a lāua	Born a firstborn to both of them

Ancestral Mountains Of Hawai'i

Terms for mountains in the Hawaiian language speak to both physical fortitude and perpetuity. The word kuahiwi translates as the "backbone" of the island, the "spine." Kuahiwi, therefore, speaks to the fortitude of an island in the face of erosion.

Another term for mountain in the Hawaiian language is mauna. Mauna is the word mau (perpetuity) + its suffix –na. The word mauna, therefore, speaks to the organic perpetuity of an island via its mountain mass. The ability for an island to maintain natural and human life-systems are largely determine by the health of its mountains. For this reason mountain tops are sacred and should not be desecrated, as they are our catchers of water.

Maunakea, Maunaloa, and Hualālai are the three prominent volcanic mountains of Hawai'i Island, and because of their contribution to our water cycles and aquifers, they have entered indelibly into the fabric of Hawaiian consciousness, especially where the land is dry and parched.

Maunakea, is not only the tallest mountain at 13, 796 ft. elevation, he is also the celestial Sire (celestial semen[v]) that titillates the three water females living on the summit of this male-mountain. Together they contribute to our continuing water source. The names of the females and their kinolau, or body forms, are Poliahu (snow), Lilinoe (mist), and Wai'au (lake remnants of a once-glacier).

A Maunakea o Kalani,	The Royale has climbed Maunakea
E 'ikemaka iā Wai'au	To experience first hand the waters of Wai'au
Kēlā wai kamaha'o	That wondrous water
I ka piko o ke kuahiwi	In the center of our island-spine.

This song commemorates Queen Emma's 1881 ascent to Maunakea to ritualize her rebirth into the highest station her rank could afford. Part of her campaigning for the throne was entering into the sacredness of the firstborn island. With Maunakea as its kīpaepae, she experienced first hand the perpetuity and fortitude of profound equilibrium on the heights of Maunakea.

Detailing the female names of water source on the top of Maunakea is realizing that the elevation of our mountains intercourses continually with atmospheric moisture, and that the product of this union is that which fills our aquifers, albeit through the forest canopy which it sustained on its slopes. We speak of water.

Mountain tops capture the moisture to support its forested slopes; these slopes in return become the "sponge" for furthering the receipt of moisture. In fact, a healthy forest can intercept water capture above and beyond total annual rainfall by as much as 30 percent.[vi] The equation that water = life is enumerated and confirmed in our familial terms and in general inquiry into the name of another.

'O Wai 'oe, literally interprets as "who's your name?" But there is only one true definition of the word wai, and it means water. Therefore, to revisit the question, "who is your name" is really to ask a person to "identify the water source from whom he/she receives life". Expounding on this is the familial term for grandparent, which is kūpuna. Kūpuna really translates as "flowing spring water." Mo'opuna, a term meaning grandchild, really translates as the "succession of springs", or the "progeny of water." So the very crux of life and living is undoubtedly reliant on water.

Hualālai Ka Heke A'o Nā Kona

Hualālai ka heke a'o nā Kona (Mt. Hualālai is Foremost to those of North and South Kona) is a phrase famed in song and chant. The word heke also means the "triangular sails on canoes." Associating the function of a canoe sail to that of the mountain will disclose an ancient posture that mountains, like sails, navigate through the wind currents to bring passengers/residents toward land with water, for who can live without water? Heke, therefore, is to be understood as an instrument to manipulate atmospheric currents; in the case of a canoe, the heke navigates toward water; in the case of a mountain, the heke propels atmospheric moisture to alight upon its slopes.

The following song is contributed by Mr. Lowell Keli'iahonui Punihaole. It commemorates their water source, Hualālai, as a sibling to Maunakea and Maunaloa.

> Lowell Keli'iahonui Punihaole was born at Makalawena ca. 1899. His genealogies tie him to the families of the larger Kekaha region.

Nā kuahiwi kaulana 'ekolu	The three famous mountain spines
O ka mokupuni a'o Hina	Of the island of goddess Hina
'O Maunakea nō me Maunaloa	Are Mauna Kea, Mauna Loa,
Muli pōki'i 'o Hualālai	and the young sibling, Hualālai[vii]

To the saying Kekaha-wai-'ole-o-nā-Kona is but an outsider's perspective at first glance, not having the intimacy of knowing that Hualālai provides this dry region with the water necessary to sustain life for many generations.

Nā Kona - Temples Microcosm Of Ancestral Mountains

North and South Kona have approximately 70 heiau of varying significance. The Kona coasts have approximately 70 temple sites[viii]. Heiau is translated to mean "temple"; temple is a place for worship; worship is defined as the allegiance accorded a deity. To some extent, this may apply to Hawaiian religion. The esotericisms encoded in heiau extend, however, beyond paying ceremonial allegiance accorded a deity.

Heiau means to be "ensnared (hei) in a space or current (au)." The macrocosmic model for our heiau is our moisture ensnaring mountain tops that sustains life. Let us look briefly at the luakini, or state heiau in the direct aegis of the paramount chief. Here you have the temple raised above the natural topography by rock terraces, this is the mountain. Now you have the roughly carved idols, or ki'i, set in place, this is the presence of deep forests. The 'anu'u tower is capital to the luakini, for this is the both the celestial phallus and vagina where continued life is fostered, secured, and manifests itself throughout the reign and territory of the paramount chief. Then you have a wai'ea, or

house of aerated water. Lele, meaning to fly off, is the altar on which are placed the physical offerings made in exchange or reciprocation to the reality of "intelligence snaring."

The use of white kapa by priest on the 'anu'u, as well as on the images, speaks to the virility of the paramount's reign as metaphored by snow on the tops of the mountain. Another meaning for 'anu'u is stairs or ladder. So when this image is juxtaposed to Queen Emma's ascent to Maunakea, she was really ritualizing the climb toward heightened awareness as replicated by its microcosms we call heiau. Maunakea is our paramount heiau!

If one can picture the coastline of North and South Kona punctuated by its panoply temples, and if one can transpose upon this heiau-dotted coastline a straight vertical line emitting upwards from each 'anu'u, you will then begin to see the emergence of a scine, a hei, whose primary function is to ensnare. To ensnare what? To ensnare the intelligence of profound consciousness.

A small extension of heiau is the simple use of the kīhei. To kīhei means "to wear a wrap over the torso area," but the ritual exegesis of this is, that to wear a kīhei is to render the wearer a human temple, an instrument qualified to "fish" from the celestial vault the intelligences necessary to live in union with other life-systems in this shared universe. Many modern day ceremonies require the use of kīhei.

If Hualālai is the heke, or sail, which directs moisture to the slopes of the Kona districts, then the heiau, a microcosm of ancestral mountains, likewise, is indeed a human instrument designed to capture and manipulate atmospheric energies toward life and living within the context of the Hawaiian cosmos. By human extension, when we don the kīhei we become the individual human instrument used to ensnare atmospheric clues on how to live in a profoundness with our environment.

Ke-ala-nui-ma'awe'ula-a-Kanaloa, literally translates as The Red Track Pathway of Kanaloa. To those privy to esotericism related to Hawaiian religion, Ke-ala-nui-ma'awe-

'ula-a-Kanaloa is really the cosmic web that stretches over the western horizon, over the ocean of death, the ocean of Kanaloa. Therefore, the heiau as a projection of a seine in the sky to capture celestial energies has its prototype. Kanaloa's web stretched over the western ocean to insure that who ever passes through are worthy of rebirth on the dawn of the next life.

I Kona, konā ke kua,	In Kona, the back is tough
I Kona ke kahuna,	For in Kona is the priest,
I Kona ke kilo,	...in Kona is the seer,
I Kona ke ali'i,	...in Kona is the chief,
I konā konohiki,	...so that the steward of the ahupua'a is strengthen,
ka lawai'a me ka mahi'ai	...along with the fisher folks and the farmers.[ix]

Although this above chant speaks to perhaps an individual of Kona's legendary past, its savoring aftertaste is nostalgic, if not realistic to the cultural-religious leadership that will come from Kona's districts. In other words, Kona western location as it relates to the life cycle of the Hawaiian, as well as Kona's quantity of heiau, Kona is equipped since antiquity as the progenitor of priest, seers, leaders, and of the model for harvesting ancient knowledge from the sea, land and sky.

Wahi Pana

Wahi Pana, or storied places, are rich and potent in its ability to inform us of traditional uses related to a locale. Wahi Pana are portals toward certain intelligences. Knowing which wahi pana to do what ceremony is integral to the Hawaiian psyche.

Oftentimes one locale will be known by more than one name. How the human interacts with a locale and vice versa is usually what underpins this. The meaning of a name is interpreted differently because of maturity. Also, un-initiates to particular intelligentsia

may forever go unknowing of the esotericism encoded in a place name. This leaves the un-initiated depending on the exoteric translation of a place.

In an oral-literate society, multiple levels of interpretation are organic elements to the communication system. Having said this, let's enter into the very dynamics of Hawaiian interpretation as they relate to a place and its spirit.

CHAPTER THREE:
NĀ AHUPUA`A O KEALAKEHE A ME KEAHUOLŪ

Having presented the greater matrix through which Kealakehe and Keahuolū are but two integral links to the whole, let us now delve into the wahipana, or storied places of both ahuapua'a.

Ahuapua'a O Kealakehe

Kealakehe - suggests in its translation a "meandering path." In mythic tones, a meandering path speaks to the trials inherent in a sacred journey. Kamiki, a mythic figure, does indeed find himself on a meandering path, a rite of passage, under the direction of his grandmother Kauluhenuihihikolo, a resident of Kalama'ula mauka. The final leg of the journey requires that he calls up the fire, the lava from the center of the earth, to remove the final obstacle in his journey. This obstacle is high chief-priest Kalualapauila, chief of both Kealakehe and Keahuolū. He wakes up Pele from her sleep, pulling upon the familial ties to aide him in removing Kalualapauila from completing his journey. She comes and covers Kalualapauila, incasing him in a cairn of lava. It is this natural lava feature that runs toward the ocean and serves as the kuamo'o, or spine that unites both ahupua'a of Kealakehe and Keahuolū. In calling up the fire, Kamiki calls up his own potential, and therefore succeeds in his rite of passage toward maturation.

A variant of Kealakehe (meandering path) is Kealakahē (path of the graves, or dead).[x] Therefore, if Kealakehe is Kealakahē, then this positions the coastline of what is known as Kealakehe as a leina, or a place where the dead "leap" into the ocean for their purification rites before returning to take their place amongst the physical family members.

Josephine Kahiwaokalani Ako-Freitas[xi] states an old proverb that says "'O Ke-ala-o-ka-hē mai ke kuahiwi mai a hō'ea I kahakai...." This translates as the "Path of the graves run from mountain down to the ocean". This proverb speaks to numerous burials in the Kealaokahē area.

> Josephine Kahiwaokalani Ako-Freitas was born at Kealaokahē in 1908.

There is no doubt as to unmark burials inland of the shore, this would be expected of the general function of an ahupua'a, but is this shoreline a leina? This reality deserves further investigation, for if Kealakahē functions as a leina then the quantity of ancestral remains may be considerable, for physical proximity to the leina lessons the chance that the soul of a beloved dead one may lose its way to milu, the underworld.

The life of the Hawaiian is a cycle, where birth and death are integral nodes to the process. Traditional burial practices of Hawai'i is to redeposit the dead relative into the physical land that once fed the now deceased. 'Āina denotes food and eating, and connotes the natural land, ocean, and atmospheric resources that supply them. Therefore, a lifetime of consuming the products of the natural living systems of your ahupua'a is reciprocated by the "planting", or kanu, of the deceased back into the land from which human life is reliant upon. Into caves, cairns and graves are the dead returned, where flesh can return to the earth and the spirit back to its soul-base, awaiting the birth of a child who will take on the name of the deceased, bringing the deceased back to the world of the physical living through the body of the child.

Re-interning the deceased back into the land was to "plant" the family into the soil of their feeder. Therefore, living in an ahupua'a planted with the remains of the ancestors imbued that parcel of land with the individual and collective mana of the ancestor, giving more power to their "water-progeny" as they continue.

Ahupua'a's residence are long-term, therefore grounds designated for burial were not necessarily marked by elaborate monuments. And because some areas were designated as seasonal residency, to elaborately mark a grave of one's ancestor was to expose the bones of your ancestor to others who may want to manipulate resources away from the family, hence the saying "Mai kaula'i wale i ka iwi o nā kūpuna" (do not discuss your ancestors too freely with strangers, it is like exposing their bones for all to see).[xii]

Concern that "ilina (burials) be protected where they lay"[xiii] is a concern of native Kona resident George Kinoulu Kahananui Sr. voiced in an interview with Kepā Maly. Mr. Kahananui's sentiment is a concrete realization now given light to the unethical Hawaiian treatment and illegal dealings associated with the Bishop Museum and the burial cave and burial artifacts stolen from a Kawaihae burial cave known infamously as the Forbes Caves.

George Kinoulu Kahananui Sr. was born in 1925 in Hōlualoa. North Kona. His adoptive parents are Joseph Kinoulu Kahananui and Haleaka Kahananui and raised him in Kalaoa overlooking Kekaha.

The paradigm of returning the deceased to the ground is the burial of Hāloa, firstborn human child of Wākea and Ho'ohōkūkalani. This still-birth was planted at the eastern corner of the house, after which the kalo grew out of the grave. The kalo is the traditional staple of Hawai'i, and with every mouthful we consume (consciously or unconsciously) the reality that our lives are stapled by the consumption of our human-brother, hence ritual cannibalism. The co-relation of burying of ancestors in family lands to that of Hāloa is the simple reliance on both physical food and spiritual guidance in the maintenance of profound equilibrium.

'Alula - pleasant feature on the mostly rocky coast of Kealakehe, it is a small sand cove. According to one account, the famous Punia final rites of passage terminated here at 'Alula with success. His submarine journey in the belly of a shark ended here when the shark, Kai'ale'ale, was convinced to land here, after which the natives of Kealakehe cut open the shark. Punia removed himself from the shark and was utterly hairless.[xiv] This image of no hair speaks to the ritual of rebirth, and 'Alula is documented as the physical place of this rebirth. This positions 'Alula as an ideal place to conduct "Hawaiian" rebirthing rituals we call kapukai and hi'uwai, both requiring ocean submersion.

A variant to 'Alula is 'Aula'ula[xv]. Peter Keka informs that he learned this name that refers to the turbulence off the coast of 'Alula.

Peter Keka was born in 1940, Waiki'i, Kohala. Both sides of his family have multi-generational ties to lands of the Honokōhau-Kalaoa section of Kekaha.

Hale-O-Kāne - a heiau on the bluff south of 'Alula. Kāne is the major deity of Hawaiian wholeness and health. A kinolau of Kāne himself is the kalo, the traditional staple. This heiau needs not only to be preserved, but its focus should be perpetuated by Kona residents.

Hale-O-Lono – a heiau significant in that it was the heiau that announced the graduation of Kona's mythic hero Kamiki. Lono worship is usually associated with rain and agriculture, especially on leeward slopes of Hawai'i. But Lono has a Vulcanian form- that of Pele's uncle and mentor, Lono-Makua (senior Lono). Lono means to be responsive to vibrations. It is interesting that most of Hale-O-Lono heiau is situated in brackish water, the water being the conduit for spiritual vibrations.

According to one source, the site is correctly named Maka'ōpio[xvi], which means the "budding of youth." This heiau can find function today as the physical place to initiate our youth into the vibrations of earth, seas and skies.

Hale-O-Manō - sometimes misspelled as Hale-o-mono, is obviously a shark domain. Perhaps the one destroyed when Honokōhau harbor was built.

Ka-Iwi - the dividing line between Kealakehe and Keahuolū, the spine of the one time shark-man of the area, Kalualapauila.

Ka-Loko-Loa - a narrow inlet in pāhoehoe between Kaluakauaka and Noio Pt.

Keomano - a rock below Hale-O-Kāne heiau.

Lae-noio- also known as Noio Pt. This lae, or precipice, is named after the noio, a tern that helps the fisher person locate aku. The ritual qualities of Noio Pt. is that the noio is associated as bird that dwells in a liminal space.[xvii] Lae Noio, is possibly a leina, a leaping off space. The activity of tern taking flight, or leina, to fish from the ocean its sustenance speaks to the similar "fishing" for clues in the western sky.

'Ōhi'a-wela - spring between Kahuaaka'ūlei and Kahihi'ie, on Kealakehe/Keahuolū boundary.[xviii]

Ahupua'a O Keahuolū

Keahuolū - translates as the "Shrine of Lū", a legendary voyager.

Halepa'u - a small fishing shrine 100ft from shore.

Hi'iaka-I-Ka-Noho-Lae - one of the function of Hi'iaka multi-function persona, is to produce light. The word lae denotes forehead and it connotes consciousness. This name, therefore, can be interpreted as Hi'iaka-in-the-seat-of-consciousness. I've been to this place, and to see that Hi'iaka is here looking out to sea is to strengthen that the western sea of death is just as integral to the psyche of the Hawaiian as is the eastern sea of birth.

"Aia i Ki'ilae" is an old proverb simply meaning that what you look for "is in Ki'ilae" (South Kona). This refers to a situation where cerebral recall of an object, or situation, or memory is "near the point of recall."[xix]

Kaiakeakua - means the 'the sea of the god.' This is a sandy beach nearby Hi'iaka-i-ka-noho-lae.[xx]

Ka-waluna Heiau - heiau on beach at Pāwai, a unique feature is that there are no openings to the heiau.

Keanawai - waterhole that sustained many houses on Keahuolū.

Palihiolo - luakini heiau rebuilt before Kalākaua sailed off in 1890 into the foreign world outside of Hawaiian Consciousness. It is said that Kalākaua ordered that this heiau be rebuilt, noting that he would make a sacrifice to it when he gets back. It is to be noted, that Palihiolo was a Luakini, requiring a human sacrifice.[xxi] Kalākaua died in Kahiki, was he perhaps his own human sacrifice? The native person sees only profound connection to all.

Papawai - site of QLCC's children's campsite.

Ka Moana Nui O Kanaloa
The Western Sea Of Kanaloa

Traditional ahupua'a were replete with access to both mountain and ocean resources. The resources of both extremes were stewarded by the ahupua'a's inhabitants. Mr. Pai speaks of the tradition of lawai'a or fish harvesting. To the un-initiated fishing is not merely going to the ocean and throwing in a baited hook and hoping for a response. Kona's methods were such that fishing grounds traditional to an ahupua'a were maintained on a daily basis. The fish were conditioned to eat at certain times and to eat certain food at certain times of the day. When the fisherperson went out to harvest there was no doubt that he would come back with food for the family.

Ko'a are fishing markers (both natural and manmade). They are found in the natural features of the land and in the ocean. Ko'a are traditional fishing markers that are inherited rights of living in an ahupua'a. Mr. Pai relates that they are about 29 identified ko'a throughout the Nā Kona districts.

Umu i'a are fish "snares" to where fish, after being accustomed to daily feeding, will be eventually harvested. The umu would be built up underwater, fed daily to condition the fish, and then it would be dismantled with the immediacy that would send the fish into the nets of the lawai'a.

Mr. Pai also speaks of a Heiau Manō once located at what is the mouth of the Honokōhau harbor. Sharks, when conditioned with food and regularity, became an essential part to the fish harvesting. Sharks were known to direct fish into the nets of the lawai'a.

I've heard that Mr. Mike Ikeda, employee of Queen Lili'uokalani Trust has an inventory of ocean ko'a along the Kona coast. This document can tremendously strengthen this CIA by incorporating into the report the inventory and associated practices and management concerns of ko'a. As the ahupua'a traditionally extends into the ocean, any development on ahupua'a should and must include its impact on the ocean. Reports such as these may lesson the destruction of the ahupua'a's full potential to feed a people.

At the point of submitting this CIA to Oceanit, I was unable to contact Mr. Ikeda. In addition, the marine report draft for the greater EIA was not available to me during the drafting of this CIA. An ocean component will make this CIA complete for the reason that, as I've mentioned, an ahupua'a included land, ocean, mountain and skies.

Flora And Fauna

The endemic plants found in this study[xxii] area are hinahina, mai'a pilo and pā'ūohi'iaka. The indigenous plants noted are mau'u 'aki'aki, 'ākulikuli, koali awahia, pōhuehue, naupaka kahakai, 'ilima, alena, alahe'e and 'uhaloa. Polynesian botanicals are niu, milo and noni. These plants continue to play significant roles in Hawaiian medicine, religion, food and shelter. This area is dominated by non-native botanicals that are already risking the continuance of native flora.

The endemic Hawaiian Black-Necked Stilt was sighted in this area. This stilt is listed as an endangered species. The Pacific Golden Plover, Wandering Tattler, and Ruddy

Turnstone are indigenous migratory species[xxiii] that continue to play important roles in traditional migration culture. The kōlea, Pacific Golden Plover, is credited for indicating land in the north and therefore a migration was launched from Tahiti to Hawai'i in the path of the kōlea. The kōlea in Hawai'i cosmology speaks to the continued relations with the south Pacific islands.

Current-Day Activities

The following activities were observed on June 10, 2006 in both Kealakehe and Keahuolū shorelines: local families and individuals gathered to pole-fish from the shoreline, groups of divers were seen in the ocean spearing, families and individuals were swimming and sunbathing at 'Alula. It was noted that two individuals appeared to be in quiet meditation south of Noio Point. It was also noted that one individual was hiking on the lava fields of Kealakehe. At Hi'iakanoholae appeared two families camping. Tourists also ventured into the Kealakehe shoreline to investigate the locale, taking photos of ocean birds and panaromic mauka views.

Mai Nā Kupa Mai- From The Natives Of The Land

The following oral interviews were gathered by Pualani Kanaka'ole Kanahele in her CIA report for the Kealakehe Commercial/Industrial Park (2001) and used with her permission. And although the CIA targets a small inland parcel for the waste-treatment site, the concerns following were selected for their timeless concern for native land. Her complete CIA is found in appendix A.

Peter Keka, kama'āina of Kona, a fisherman and stacker of rock walls, says that inland of Kealakehe was not inhabited (p. 30).

Michael Ikeda, local fisherman, resident of Kona for more than 30 years. He is employed by Queen Lili'uokalani's Children Center and is known throughout the Kona regions for his knowledge in ko'a fishing methods. His concern is for off shore fishing that could be adversely affected by waste water and large tourist boats (p.31).

Māhealani Pai, a native of Kona, is concern for the ko'a fishing culture and its negative impact by development. He "fears" that continued development of the shoreline will cause irretrievable lost to the fishing resource (p. 32)

Elaine Watai, resident of Jack Hall Housing, wants to revive the mauka-makai trails to reestablish the function of ahupua'a (p. 32).

Angel Pilago, long-time Kona resident, is not "comfortable with the bulldozing of cultural sites…", and continues to say that size and significance of site does not matter (p. 32-3).

David Roy and Mikihala Roy, well known Kona natives, are concerned with water quality that will eventually leak in ponds and into the oceanfront (33).

CHAPTER FOUR:
REPORT SYNTHESIS

I do by synthesize this report by stating that the lands of Kealakehe and Keahuolū, although obviously absent of full-time residents, are nevertheless integral to the recovery of the sacred in our modern lives. The "meandering path" of Kealakehe may refer to the Alanui trail systems that took an itinerant from the realities of one ahupua'a to the realities of another, but always on a mundane, horizontal plane; it may even connote sacred peregrinations, one of which is documented in the kā'ao of Kamiki. The latter speaks to the rites of passage once a part of the daily living-scape of its human residents.

Kealaokahē, "The Path of Graves," is sobering in that it alludes to possibly large scale burials in close proximity to a leina, a physical place where the souls of the departed make their final jump into the underworld, into Milu, to finalize and begin to ascent back up into the living as either 'aumakua or reincarnations through their mo'opuna or grandchildren. This is the extreme vertical journey at death. Ka Lae Noio is factored into this equation in that the noio, or tern, lives in a liminal space between land and ocean, the metaphor for life and death. This tern also sustains itself on the fish in the ocean, a process that gives clue to the fishing traditions of the coast as to the location of aku. Drawing similarities from this image is that we too rely on our dead to continue to inform us as we move on the currents of always living in the now.

Keahuolū's "Hi'iaka-in-the-seat-of-consciousness" or Hi'iakaikanoholae is still used today by those initiated into the Pele Vulcanian culture of Hawai'i. Hi'iaka is the female consciousness we inherit at birth, to be in the proximity of its land manifestation is to be ensconced in ritual oneness with this reality.

Palihiolo heiau is very significant to the journey of Hawai'i's last king, King Kalākaua. He giving order to reface and prepare this heiau so that after his return from Kahiki he would make the necessary sacrifices. Palihiolo is a luakini, whose temple service incorporated the extreme life-for-life rituals in the form of human sacrifice. I believe that Kalākaua prepared this heiau to receive his human sacrifice so that his soul may begin function on a higher plane in the advancement of his people and their natural resources. During his time, hula, the aesthetic portal to deeper consciousness, found public stage. This meant that no longer were the gods dormant. Here the gods could function through the dancer and the chant to return the spectators a condition of profound balance. During his time there was an eruption of sacred stories via newspapers serials. His motto was to increase the Hawaiian race. The increase of the race was to increase the amount of incarnated ancestors into the physical living systems of Hawai'i. The equation of more descendants = greater ancestral guidance is to be understood here. His 'Iolani Palace was corner-stoned with a stone from Kūki'i Heiau in Puna in the east, his physical reign ended with his soul returning to Palihiolo Heiau in the west. There was no guess that he was going to die, for Hawaiians of old were connected to such knowing. Queen Kapi'olani is the validation to this in that she composes Ka Ipo Lei Manu, a lovely song still sung today that speaks of her feather lei Kalākaua as going away and not returning.

The ancestral mountains of Kealakehe and Keahuolū are integral to the life systems of both ahupua'a. Mr. Māhealani Pai, who, I will disclose with his permission, is an initiate to the sun religion under the aegis of Hi'iakaikapoliopele. I know this of him as I myself am an initiate into this religion. Mr. Pai's concern is that the sunrise over Hualālai as experienced from this coast may forever be obliterated by large-scale construction. To not see the sunlight moving over the slopes of the mountain is to render the practitioner blind from all omens related to this religion.

Concluding this synthesis, I wish to invite all readers of this document to require of you that every decision and action you make that impacts these living ahuapua'a are done from a foundation underpinned by profound equilibrium as promulgated by Hawai'i's Kumulipo Creation Chant.

CHAPTER FIVE
RECOMMENDATIONS

In hierarchal order, I've listed the recommendation that we believe will provide a basis to help the developer of Kona Kai Ola with the grounds for responsive development.

1. It is recommended that Jacoby launches a full inventory of archaeological sites on or contiguous to the development - especially where burials are located.
2. It is recommended that the developers react responsive to burials should they be exposed
3. It is recommended that the developer employs a fulltime culture practitioner proficient in mitigating the concerns related to the life-systems of the project area. By life-systems I mean human and non-human, dead and alive.
4. It is also recommended that a marine impact assessment be available to further investigate the probable impacts the land development will have on the ocean and its related sustenance activities.
5. Access to the shoreline should be open and without censorship. For a fisherperson or religious practitioner to report to gate keeper into the purpose of shoreline access is to render the journey moot. The fish will run away, the omens will disappear.
6. The ancestral mountains are not to be obstructed. Visual obstruction is desensitizing to the senses. To not see the mountains from any point of the land is to promote cultural desensitization.
7. Concern for the management of waste water is valid and should be addressed.
8. Concern for cruise ships in the area is also valid and needs to be addressed.
9. Open access to the cultural resources should be available in a manner that will encourage native Hawaiian and local residence to use.
10. Green development is most sensitive to the environment and therefore should be required.
11. To keep the place Hawaiian, Hawaiians must live on the property. The promise of employment is good, the prospect of having nice parks and recreation are also

nice. But if the target residential populations are non-Hawaiians then what we end up with is a greater marginalization of native peoples in their own domain.

Conclusion

I believe that Kona Kai Ola (Kona of the Thriving Ocean) can and should become the model for a development that is *responsive* to the delicacy of Hawai'i's biospheres. The traditional Hawaiian has no escape from this biosphere. They are born here, they sustain themselves on it, and they die and return to it in spirit or through the incarnations of their mo'opuna. The methods for making every decision affecting this biosphere required that the action always be founded on profound equilibrium of knowing how far forward we can reach without losing irretrievably our connection to the life-systems of Hawai'i. To live in the extremes of either antiquity or modernity is not the route. Finding the profound center of both extremes is always the goal, the secrets of the sages.

To remember that the Hawaiian will return to Hawai'i in every cycle of their living is what requires them to make the best decisions in this physical life, for the decisions they make today are the ones they have to return to tomorrow.

This project can learn from the Hawaiian and should, for Hawaiians are the longest residence of these districts and therefore know the idiosyncrasies of a given locale. It was in best cultural form to treat malihini, or transients, to Hawai'i with a decency that Hawai'i is known for. The decency in which we treat our transient residents is waning because much of the decisions on how we live as natives or long-term residents of this land are times often determined by the needs and tropical ideals of transients. Let Kona Kai Ola become t he model development that will have a long life on one of Hawai'i's sacred ahupua'a.

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Appendix L-2

Cultural Impact Assessment 2001

By Pualani Kanaka'ole Kanahele

CULTURAL IMPACT ASSESSMENT

PROJECT TITLE

KEALAKEHE COMMERCIAL / INDUSTRIAL PARK NORTH KONA ISLAND OF HAWAI'I

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for Department of Hawaiian Homes Land

by Pualani Kanaka'ole Kanahele

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EXECUTIVE SUMMARY

At the request of PBR Hawai'i on behalf of their client Department of Hawaiian Homes Land (DHHL), Pualani Kanaka'ole Kanahele (Pua Kanahele) conducted a Cultural Impact Assessment (CIA) on the DHHL 200 acres of Industrial/Commercial Development project area (TMK: 7-4-08: por. 3) located in the ahupua'a of Kealakehe, North Kona District, Island of Hawai'i. This CIA is in conjunction with the Environmental Impact Statement (EIS) being prepared for Kealakehe.

Methodology for Study

The study for information was conducted in six components for the specific land area within the ahupua'a of Kealakehe; 1) the study of maps, 2) archival documents, 3) historical material, 4) pre-historical literature, both in chant and narrative form 5) walking / diving the area in search of cultural sites, water quality, flora and fauna 6) and oral history. The oral history included kama'aina (native of Kona) and others who are now living in Kona and are interested in the welfare and use of Kealakehe.

A perspective of Hawaiian cultural intelligence as it refers to land as an entity, is included in the introduction portion of this report. Clarity of thought is a problem for many Hawaiians who possess an innate sense of land value but lack the knowledge to articulate their indigenous reaction. This information is fundamental for any land use cultural report, because it pinpoints one of the sources for indigenous reasoning and thought process.

The CIA will orchestrate an interpretation from the above information gathered. Included in the interpretation are past land uses, contemporary land use and recommendations for land use by the interviewees. Opinions shared by the interviewees also take into account disagreements as well as agreements with DHHL's use of Kealakehe ma kai (seaward).

All studies of this project was done from October 1 – November 12, 2001 by Pua Kanahele and her staff.

Cultural Introduction

Cultural Description of the Indigenous Hawaiian Lifeways

One of the most substantial and profound literary material the Native Hawaiian possesses is the Kumulipo. The Kumulipo is a document of the continuing creative/procreative processes in the Native Hawaiian environment. These creative/procreative energies comprise of land and ocean growth with the parallel nature of the flora and fauna of both realms. Eventually it involves the human being and mankind's growth and accountability for his expansion, history, spirituality and political hierarchy.

The Kumulipo has two thousand one hundred and two lines which concepts have been taught for generations among practitioners, kama'aina (people of the land) and ali'i (people with diverse ranks). The first age of the Kumulipo does not dictate doctrine or command decree, its purpose is to 1) <u>list creative entities according to their importance for mankind's survival</u> 2) reveal modes of incubation and nurturing 3) and finally to create the order of primary creatures from the lowest life forms, who lend to the food chain and building process for all living things and eventually listing higher life forms.

The specificity of creative entities listed in the Kumulipo transcended from oral communication to an innate ability to know without continued verbal accountability or reminder overtime. Today the Native Hawaiian continues to use this intuitive sense without knowing how to defend its existence. The foundation for the Native Hawaiian's existence, in Hawai'i, is <u>land</u>. Land is their foundation and is essential to their identity.

The Kumulipo not only list all things in this environment but also give the relationship of flora, fauna, human and elemental forms to each other. The chant below is a small introduction to the Kumulipo using particular lines to draw focus to the objectives stated above:

<u>Kumulipo – Ka Wā 'Akahi</u>
Kumulipo – The First Age

1. 'O ke au i kāhuli wela ka honua	Time was altered when the earth became hot
2. 'O ke au i kāhuli lole ka lani	Time was altered when the sky turned inside out
3. 'O ke au i Kūkaiaka ka lā	The time when the day was dark
4. E ho'omālamalama i ka malama	Brightened only the moon
5. 'O ke au o Makali'i ka pō	A time of the constellation, Makali'i
6. 'O ka walewale ho'okumu honua ia	The earth originated in the slime
7. 'O ke kumu o ka lipo i lipo ai	With its origins in darkness
8. 'O ke kumu o ka pō i pō ai	With its origins in the night
9. 'O ka lipolipo, 'o ka lipolipo	Darkness, darkness
10. 'O ka lipo o ka lā, 'o ka lipo o ka pō	Darkness of the day, darkness of the night
11. Pō wale ho'i	Engulfed in darkness

12. Hānau ka pō	The night is born
13. Hānau Kumulipo i ka pō, he kāne	Kumulipo gives birth in the night to a male
14. Hānau Pō'ele i ka pō, he wahine	Pō'ele is born in the night, a female
15. Hānau ka 'Ukuko'ako'a, hānau kāna,	The Coral gives birth to an offspring,
He 'āko'ako'a, puka	The coral head emerge
16. Hānau ke Ko'e 'Enuhe,	The Caterpillar Worm gives birth,
'Eli ho'opu'u honua,	Digging up the earth,
17. Hānau kāna , he Ko'e, puka	The Worm emerges
18. Hānau ka Pe'a,	The Starfish gives birth,
Ka Pe'ape'a kāna keiki, puka	The small starfish emerges
19. Hānau ka Weli,	The Sea Cucumber gives birth,
He Weliweli kāna keiki, puka	The small sea cucumber emerges.....
40. Hānau kāne iā Wai'ololī,	Wai'ololī is the product of males,
'O ka wahine iā Wai'ololā	Wai'ololā of females
41. Hānau ka 'Aki'aki noho i kai	The Course Red Seaweed gives birth
	Found in the sea
42. Kia'i 'ia e ka Mānienie 'Aki'aki	Guarded by the Rush Grass
Noho i uka	Found in the upland
43. He pō uhe'e i ka wawā	The night becomes tumultuous
44. He nuku, he wai ka 'ai a ka lā'au	Ranting, plants are sustained by water
45. 'O ke Akua ke komo,	The god enters,
'A'oe komo kanaka.	Man does not have access.....
112. 'O ke kāne huawai, Akua kēnā	The male with the water container,
	That is the god.....

The composers of the Kumulipo list five basic elementary components needed to initiate and maintain life. The composers listed them in the order for survival of all life, as understood by the Hawaiian world view, beginning with "honua" which is interpreted as earth, land or world. Through many generations, the Native Hawaiian have been verbally reminded of the sacredness or importance of land and ocean as nurturing providers for life to exist. The honua being the very first elementary component mentioned in the Kumulipo emphasizes and reiterates that this is the elemental form most vital for the existence of all creatures.

The creative entities or elementary components following honua are again listed in their order of significance with earth and sky as the leading pair complementing each other. The day or sun, moon and star provide energy for growth; these are also the mechanism for measuring time. The above elemental forms mark the daily, monthly and yearly cycles.

Line #6 takes into account that walewale is inclusive of all possible substances of the earth needed to incubate and nourish during the incubation period. The walewale parallel the amniotic fluid for the human fetus. One of the prescribed states for incubation

is darkness. A different quality of darkness is described through each of lines #7 to 14. The first birth of substance is the coral and coral head, which begins the food chain and building process for life in the ocean. Lines #16 and 17 introduce the earthworm and the life process for living creatures of the land. The lines with the star fish and sea cucumber continues the births of the ocean while lines #40 through 45 parallel the plant life of the ocean and land with water as their primary sustenance. Line #112 is most interesting because it names the thing, which contains the life giving substance, wai or water, as the god. The first age of the Kumulipo begins with land, the first substantial birth is coral and the life force is water.

Kealakehe ahupua'a possess all of the natural life giving substances mentioned in this ancient chant. Kealakeha is a sustainable land section, it has an upland forest, the ocean is teaming with life around the coral beds and fresh/brackish water is available at the shore and has been for generations. There are pockets of rich dirt for farming in the project site. This philosophy of land having life substance is not of the past but has the same value today as yesterday. This is the argument for many "activist Hawaiians".

Kekaha-wai-'ole-o-na-Kona

The ahupua'a from Kalaoa (Keahole Point) to Kealakehe were known as "Kekaha-wai-'ole-o-na-Kona" or the hot, dry, waterless shores of Kona. Despite the fact that the land had this reputation another description was found in the Hawaiian Newspaper "Ka Hōkū Hawai'i" which was the practice among the people of Kekaha-wai-'ole-o-nā-Kona in the late 1800's and early 1900's:

> 'O ia ka wā e ne'e 'ana ka lā iā Kona, hele a malo'o ka 'āina i ka 'ai kupakupa 'ia e ka lā, a o nā kānaka, nā li'i o Kona, pūhe'e aku la a noho i kahakai kāhi o ka wai e ola ai nā kānaka. (It was during the season, when the sun moved over Kona, drying and devouring the land, that the chiefs and people fled from the uplands to dwell along the shore where water could be found to give life to the people.) [Kepa Maly]

This clearly communicates that the natives of Kekaha-wai-'ole had great knowledge of their land's cycles and its productive abilities. There were springs and brackish water ponds inland from the shore and the ocean was abundant. They planted in the ma uka or upland forest and had sufficient amount of rain for their crop. When the rainy season passed, they camped at the shore, grew sweet potato, and fished. Their basic needs were satisfied.

The Ahupua'a of Kealakehe, Ma Kai

Kealakehe is interpreted in two ways 1) Kealakahē, with the emphasis on the last syllable, this translates as "the pathway of graves", 2) Kealake'e, with an 'okina replacing the "h", is the more popular definition which means "winding path". There is no definition for Kealakehe as it is spelled today, however according to the Hawaiian language dictionary, the last two syllables, "kehe" is considered a spelling variation of "ke'e" and vise versa.

Ahupua'a Boundaries

Honokohauiki is the northern boundary of Kealakehe, both ahupua'a travel ma uka until Honokohauiki runs into Honokohau. The junction of Kealakehe, Honokohauiki and Honokohau was known as Kahi'ihi'ia and is now written as Kahīhīa.[Kepa Maly] Both Kealakehe and Honokohau continues ma uka to the Honua'ula Forest. This is Kealakehe's ma uka border, however Honokohau continues to the ahupua'a of Ka'upulehu, which is in the upper regions of Hualālai. Keahuolū ahupua'a is the property of Queen Lili'uokalani Estate and is Kealakehe's southern border. Honua'ula forest is the ma uka border for both Kealakehe and Keahuolū.

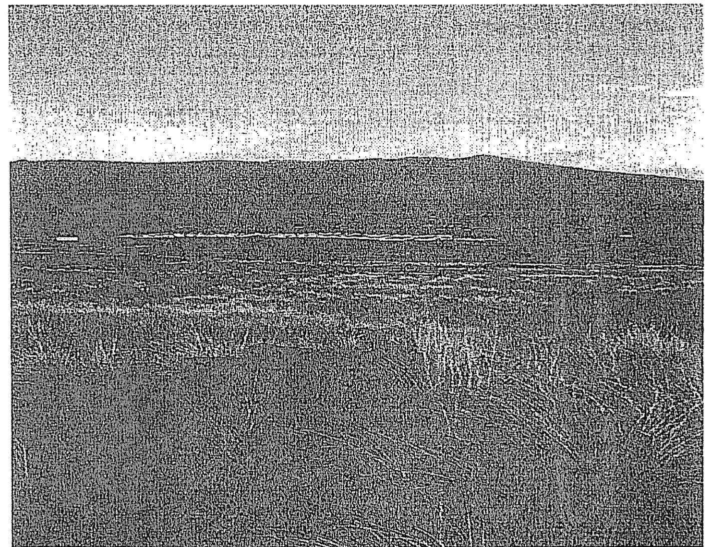
Shoreline Features

Kealakehe has several outstanding ma kai or sea shore features. Maliu is the point separating Kealakehe and Honokohauiki. Two generations ago Maliu was only a large rock at that point and the point was known as Puuoina.[Peter Keka] The name Pu'uoina has now disappeared. The little bay on the south end of Maliu housed a shark hole and was known as Hale Manō.[Mahealani Pai] This is now the entrance to the boat harbor. The shark frequenting that area and lived in the above shark hole was/is a tiger shark named Papakonane.[Mahealani Pai] Another tiger shark who occupied the area north of Maliu was known as Hi'upelu.[Mahealani Pai] A structure at Maliu was known as Hale Mono. Very little is known about this site except that it may be a female heiau.[Peter Keka] The Honokohau small boat harbor is in the ahupua'a of Kealakehe.

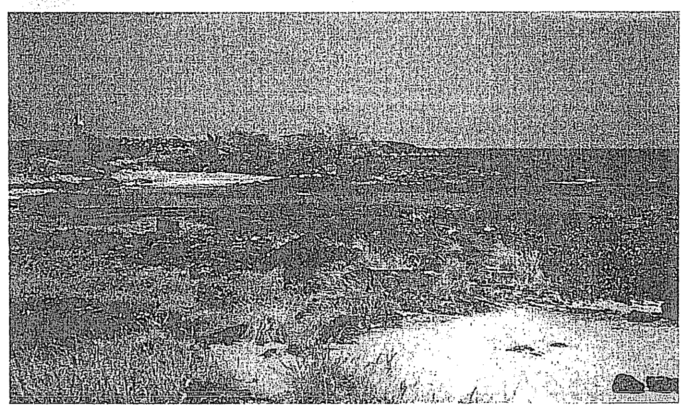
'Alula Bay

South of the harbor is a white sand beach known in chants and stories as 'Alula. In Emerson's map of 1888, 'Alula was a canoe and small boat landing.[Kepa Maly] According to some kama'aina the original name for this beach was 'Aulaulā.[Mahealani Pai & Peter Keka] The extended version of the original name describes the current of that bay as being broad. 'Alula is susceptible to inundation of the northwest swells, which travels quite a ways inland. There is an 'ōpelu ko'a or an 'ōpelu fishing ground in the Bay of 'Alula.[Peter Keka].

The story of Punia, found in "Hawaiian Antiquities and Folklore", mentions the people and beach of 'Alula. "Punia was carried around in the shark for about ten days, when at last the shark began to grow weak and made its way back towards land, arriving outside of Kona, at a place called 'Alula, directly out of Hi'iakanoholae. This was the only place where there were any people, all the rest of the place round about Kekaha was inhabited by ghosts."



Kealakehe Ahupua'a (Above) **'Alula Bay (Below)**



Hale o Lono

Hale o Lono heiau was built in a fresh water pond on the northern shore of ʻAlula Bay. Hale o Lono is a structure made to impress and evoke the deity with the same name. It appears to have some protection from high surf as it abuts a low outcrop of rocks to the north and is around the corner of the incoming tide. Because of age and neglect, this heiau has lost some of its major setting stones which sits near the ocean and does not seem to have any chance of reparation in the future. Hale o Lono heiau was built to evoke the god Lono during makahiki season for abundant rain, greenery and enough fresh water to last through to the next heavy rain season. Lono heiau was also used to train priest of this class for further proliferation by encouraging the manifestations of both ocean and land growth along with water flow during the winter season for Kekaha-wai-ʻole. Lono heiau was used for subincision ceremony or "kā imua" for a male child when he was considered ready for manhood. Hale o Lono is one of the most important man-made cultural structures in Kealakehe. It is a reminder and a reawakening of the cycles of creation and procreation involving human beings, ocean and land flora and fauna. It is the reiteration of the Kumulipo.

The kaʻao, Ka Miki, was written about 1911 by John Kihe. Mr. Kihe was an educated Native Hawaiian who was born in Kaloko Honokohau area and tells this story using the techniques of Hawaiian fiction or kaʻao to describe Kekaha-wai-ʻole, his home. In the kaʻao of Ka Miki, Haleolono is a sweet potato farmer who lives in Kealakehe and is married to Pipipiapoʻo a female from Kohanaiki. Pipipiapoʻo was the name of a substantial hala grove at Kohanaiki. This is a typical Hawaiian fiction trait, using place names as characters in a story.

Fresh Water Pond

One of the references site the fresh water pond ma uka of ʻAlula as the ʻAiʻōpio pond.[Keka] The ʻAiʻōpio fish pond is in Honokohauiki. Most kamaʻaina of Kona do not recollect the name for that particular pond ma uka of ʻAlula. The ʻAiʻōpio pond is a known habitat for ʻōpae'ula or red shrimp used as bait for ʻōpelu. All of the alkaline ponds of the Kona coast had an abundant amount of ʻōpaeʻula readily available for ʻōpelu fishing. ʻŌpaeʻula ponds have deteriorated as ʻōpaeʻula loses its popularity with ʻōpelu fisherman. It has becoming more of a chore to clean the ponds therefore the contemporary fishermen prefer to use bread. The fishermen at south Kona still use ʻōpaeʻula and pumpkin. This pond now houses talapia which means that the ʻōpaeʻula population has been minimized tremendously.

Hale o Kāne

Traveling south above ʻAlula Bay are two structures at that point. An older map listed them as Hale o Kāne. No one I talked with was able to provide the name or the function for the structures. The stories or chants did not provide a name for the structures except for the 1888 map of J.S. Emerson.[Kepa Maly] The other Lae or point often mentioned is Ka Lae Noio. I assume that this point was named for the noio bird.

Hale o Lono Heiau

ʻAiʻopio Pond

Hale o Kāne Heiau

Surfing, the Sport

A surfing chant honors the famous surfing waves of Kona beginning with Keolonahihi and Holualoa eventually ending at Kīholo to the north. It touches upon three places of Kealakehe.

He'e mai Hi'iakanoholae	Hi'iakanoholae surfs
He'e nā 'Alula i Kealakehe	'Alula surfs at Kealakehe
He'e i nā nalu o Kaiwi.....	Surfing the waves of Kaiwi.....

Another sport mentioning Kealakehe is the game of "Lele Koali". A rope eight fathoms long is fastened to a coconut tree. At the time of swinging, the person swinging, either man or woman is decently appareled. Two persons pull the swing. When the swing has oscillated high the rider chants to make the swinging more enjoyable. The chant mentions some sea cliffs, ocean winds and splashing waves. This is a short chant mentioning the forested cliffs of Kealakehe.

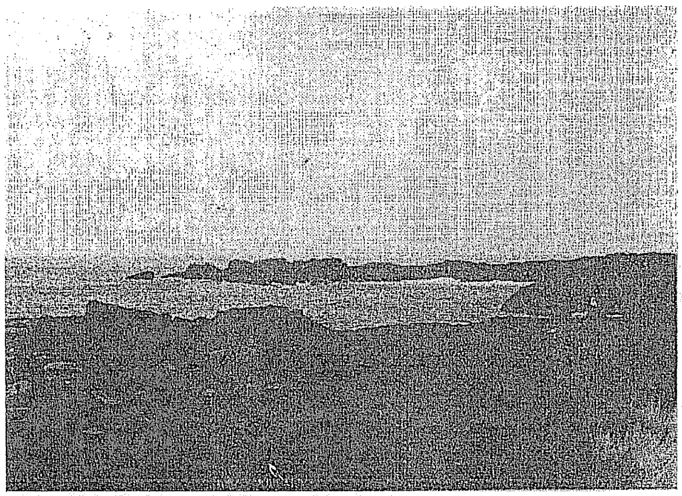
Ola nā hulu'ai a ka makani	Surviving the wind
Kākā ka uhu o Hanala'ila'i	Fishing for uhu of Hanala'ila'i
Ka pali ku'i lā'au o Kealakehe koea	The notched forested cliffs of Kealakehe has eroded.
Ke'ehi 'ia e ka makani	Tread upon by the wind

Ka Lae o Kaiwi – Kaiwi Point

Kaiwi is the point on the boundary of Kealakehe and Keahuolū. According to the fishermen of the area, Kaiwi Point houses a mamamo ko'a. Kaiwi has an intriguing story connected with Ka Miki. In this ka'ao, Kaiwi is a shark and Kalualapauila is the Kahuna of Kealakehe. Kaiwi and Kalualapuila are the same entity. Eventually the grandmother of Ka Miki, Kauluhenuihihikolo, discovers this dual identity when the shark becomes a man-eater and plans to destroy him. Kaiwi-Kalualapuila are both destroyed when the grandmother teaches her grandchildren to call up the fires of Pele to rid the land of this man eating shark. Hi'iakanoholae, known today as Ka Lae Keahuolū, was the boundary direction for the lava flow. The protocol for lava is that a course of flow is given and Hi'iakanoholae is the southern limit for the flow. The flow did exactly what it was asked to do with Kaiwi and the characteristic of a Hi'iakaikeale'ī and Hi'iakaikealemoe flow is seen at Kaiwi point. This ka'ao concerning Kaiwi is interesting because it provides information indirectly with the chant below. The chant describes a cultural practice of man's association with an elemental form as it tells the story of Kaiwi Point and the possible lava flow of those two land sections.

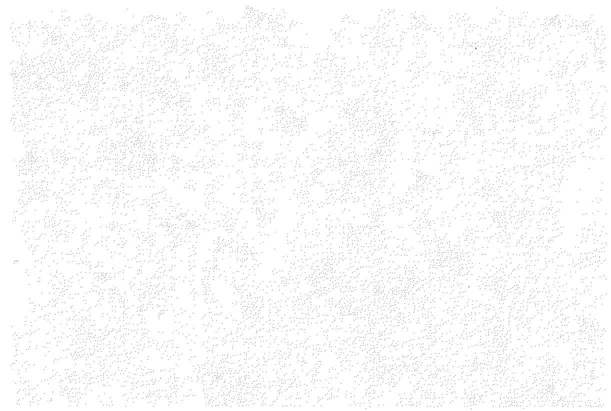
E ala e Mihakalani, Mihakahonua	Awaken, silence of the heaven / of the earth
E ala e Pele Honuamea	Awaken Pele Honuamea
E ala e ke kumu o ke ahi o Hulinu'u	Awaken source of the fire of Hulinu'u
'O Hulinu'u ke ahi a loa naueue Tahiti	Hulinu'u is the fire moving far from Tahiti
Ho'ohaku'i nei nakolo ka leo o ka pohaku	Breaking, the reverberating sounds of rock,
Nawewe 'uina ka ua maka o ka uwila	The downpour roars, cracks in the face of the lightning
Nakolo nakeke i ke mole o Ho'okumuhonua	Shaking the core of Ho'okumuhonua
'Ōlapa ke ahi kulapa i ke kai	The fire blazes as it plows toward the sea
Hulihia kapua'i e Pelehonuamea lā e,	Overturned are the tracks, e Pelehonuamea
Ke'ehia iā Lani-pipili i ka maka o ke Akua	Treading on Lanipipili the eye of the god
Ke'ehia iā Ho'okumuhonua Papa la	Treading upon the very foundation of Ho'okumuhonua
Ke'ehia i ka heiau o Kalualapauila	Treading upon the temple of Kalualapauila
'O Hoali i ke ahi a Lonomakua	Strike the fires of Lonomakua
'O ke ahi wela ke kumu o ka 'aunaki	The hot fire at the base of the firestick
'O ke ahi lalapa i ke kumu o ka 'aulima	The fire sparks at the base of the firestick
Wahia ka lani, wahia ka honua	The heavens are rented, the earth is split
Kau ka ha'ea ke ao uahi	The cumulus clouds gather, the smoke cloud
Ea mai Pele kauluwela nā moku	Here is Pele the growing heat of the islands
Ko hiamoe kapu e Pele e	From your sacred sleep
A ala ho'i e Hulinu'u ke kumu o ke ahi	Hulinu'u the source of fire, awaken
Kuhia i ou poki'i la,	Your siblings are chosen
I ka 'ale'ī, i ka 'ale moe	The erect wave, the flat wave
E Hi'i e, E Hi'iaka	Say Hi'i, say Hi'iaka
E Hi'iaka-i-ka-'ale'ī	Say Hi'iaka-of-the-erect-wave

E H‘iaka-i-ke-‘ale-moe	Say Hi‘iaka-of-the-flat-wave
Moe a i kai la	Flattening out towards sea
I ka heiau o Kalualapauila	To the temple of Kalualapauila
I ka i‘a kino akua kino kanaka	The fish body and the human body
I ka manō nahu imihala e	The trouble making biting shark
‘O Ka‘iwi ka inoa lā	The name is Kaiwi
‘Aina ia a pahoehoe kino pohaku	You are consumed by pahoehoe, turned to stone
Pohaku kino i‘a no ka heiau, halo-pa	A rock fish for the temple, swimming
Elieli kau mai e	A profound endeavor
Eō, i ko inoa	Answer to your name
‘O Pele Keahialoa la e, noa.	Pele Keahialoa, it is free.



Ka Lae o Kaiwi

Hi‘iakanoholae or Ka Lae o Keahuolū



Kealakehe Project Site Description

Vegetation

At first glance, Kealakehe kai or the project site seaward of Ka'ahumanu highway is barren and desolate except for dry grass and foreign plants. The project site has as much native vegetation as is expected in the Kekaha-wai-'ole land. The variety of native vegetation there, was / is still being used in Hawai'i.

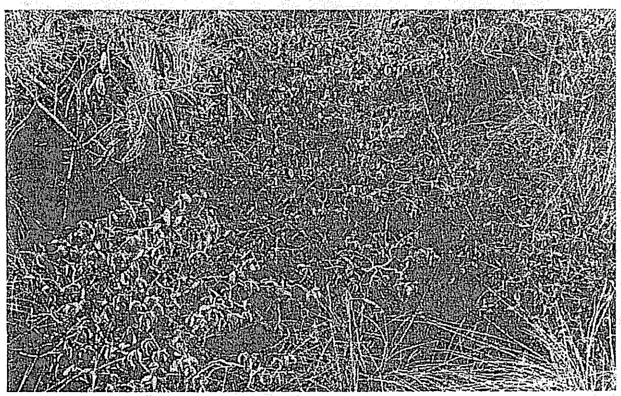
The intrusive or introduced vegetation within the area are common through out the dry areas of the main islands of this chain many of which the Native Hawaiian was able to utilize. These plants however are invasive of the space used by native vegetation. One of these are the 'ekoa or haole koa known also as false koa (Leucaena glauca). The Wililaike or Christmas berry (Schinus terebinthifolious) was worn by William Rice, hence the name Wililaiki. Another name for this berry is Nani-o-Hilo. The lantana (Lantana camara) or lakana in Hawaiian is not a useful plant. The Hawaiian nomenclature was adapted to the English pronunciation. These are weeds in Hawai'i and grows everywhere space is available.

Native flora of the project site is interesting to me although common to the dry lowland and kula areas. The most common native plant of Kealakehe-kai is noni (Morinda citrifolia). This is not exceptionally plentiful in Kealakehe-kai, however, they are healthy fruit bearing plants. Another indigenous flora is the 'a'ali'i (Dodonaea viscosa). The Ka'ū people boast the characteristic of the " 'a'ali'i kū makani or the 'a'ali'i, no wind can push over." The uniqueness of the 'a'ali'i at Kealakehe, is the color of the seed pod which is golden brown. Other 'a'ali'i vary in colors from green to yellow to pink to red to crimson. The pua pilo (Capparis sandwichiana) is a dry land plant with pungent flower. Another plant found in the upper and lower dry forest and also in the wet forest of Pana'ewa is the lama tree (Diospyros). The lama is perhaps the one vegetation on this site that is considered sacred. However, because of the weather condition of Kealakehe-kai the lama does not grow to the size of a large tree which trunk is used for the hula kuahu or dance altar. The kupukupu fern (Nephrolepis biserrata) is found here, however, they hide under ledges and are not plentiful. The tips were eaten and the small frond can easily be woven into a lei to keep the head cool in a hot area such as Kekaha-wai-'ole. The 'ilima (Sida fallax) flower is brilliant yellow and its leaves complement the yellow with a bright green color which is outstanding in an area predominantly brown and dry. This variety of 'ilima is much like the kula rather then kū kahakai or kahakai kolo (crawling 'ilima). When plentiful, a lovely lei is braided using the whole branch. The 'ilima was used medicinally. Common and plentiful the 'uhaloa shrub (Waltheria indica) is an effective medicinal agent for colds, asthma and sore throat. One of the interviewee's recalled that the pili (Heteropogon contortus) was plentiful in the ma kai Kealakehe and Keahuolū ahupua'a.[Peter Keka] During the days of the hale pili, different vegetation were used depending on the availability of the supply and pili was available in these areas. We think we found one lonely pili grass in the Kealakehe project area. One moa (Psilotum nudum) was seen in the project area, there may be more however it favors the shady spots.

Noni
Morinda citrifolia
MK - 1

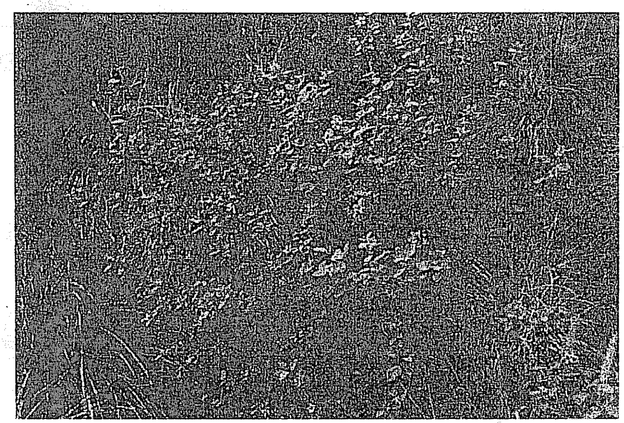
'A'ali'i
Dodonaea viscosa
MK - 2

Puapilo
Capparis sandwichiana
MK – 3

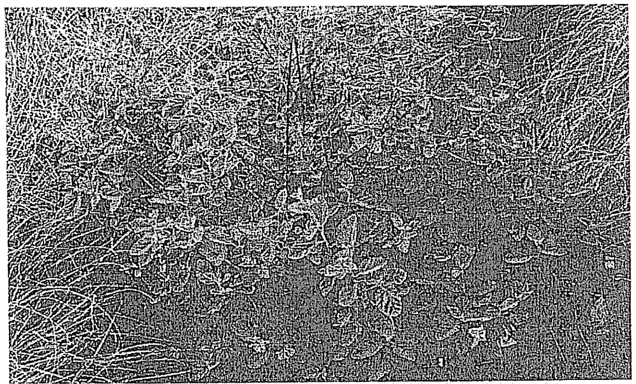


Lama
Diospyros
MK – 4

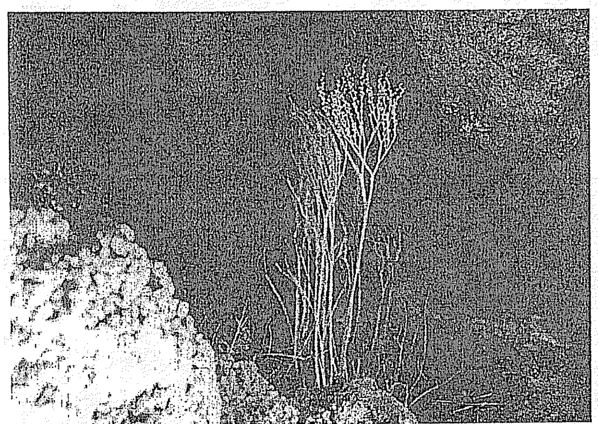
Kupukupu
Nephrolepis biserrata
MK - 5



'Ilima-
Sida fallax
MK – 6



'Uhaloa
Waltheria indica
MK - 7



Moa
Psilotum Nudum
MK - 8

Plants and their uses:

Foreign Plants and their uses

Hawaiian Name	Scientific Name	Common Name	Uses
'ekoa	Leucaena glauca	Haole koa False koa	Cattle feed – seed Leis – seed & pod
Wililaiki nani o Hilo	Chinus Terebinthifolious	Christmas berry	
Lakana	Lantana camara	Lantana	
Panini		Cactus	Fruit is eatable

Native Plants and their uses

Hawaiian Name	Scientific Name	Common Name	Uses
MK–1 Noni	Morinda citrifolia	Indian Mulberry	Famine food – fruit Medicine – fruit, stem, bark Dyes – bark, roots Drink – fruit Insecticide – fruit
MK-2 'A'ali'i	Dodonaea viscosa		Leis - seed pods, Housepost – wood
MK-3 Puapilo	Capparis sandwichiana		Medicine for broken bones – the entire plant
MK-4 Lama	Diospyros		Fruits – eatable Trunk used on Hula kuahu Kinolau of Laka Fence post for heiau – trunk
MK-5 Kupukupu	Nephrolepis biserrata	Sword fern	Shoots – eatable Leis Ground cover under mat
MK-6 'Ilima	Sida fallax		Medicine – leaf bud Lei – flower
MK-7 'Uhaloa	Waltheria indica		Medicine – entire plant
MK-8 Moa	Psilotum nudum		Powder – spores Games – stems

Plants Used Today

Most of the plants mentioned above are used today. The only plant not used, is the pua pilo. This is common on the dry side of Hawai'i and not seen at all on the windward side of this island except in the Volcano National Park. The plant with the international status is the noni. The noni is Polynesian introduced and was a valuable plant for many reasons. Some of the uses are listed above however it was also used for high blood pressure, menstrual cramps, ulcers, etc. Today, hālau or hula schools use the dyeing agents found in the bark. It will produce a yellow dye however with lime in it the yellow will turn pink. The noni is internationally known and used in the market as medicinal and found also in shampoo and soap.

The 'a'ali'i is highly desired for lei today by many halau for dancing purposes. It is plentiful throughout the islands. Because of the dryness of this land, the seed pods do not have the common pigments as those found elsewhere, therefore, this color is unique.

The 'ilima lei is used often and is highly treasured and desired today. It is elegant and was prized by ali'i and in many places reserved for their use only. The flower was delicate and one lei utilize hundreds of flowers. Today the 'ilima is cultivated for lei making. However, the wild 'ilima braided with the grayish, green leaves are used also prized.

Kupukupu is common for the backing of a lei. The kupukupu lei is not an item for hula, because the fern is plentiful and is not a kinolau, it is a fun lei for adornment purposes only. None of the above vegetation, however, are on the endangered list.

Waterfowl

The wastewater project attracts Hawaiian waterfowl. The most obvious is the 'auku'u or the black-crown night heron (Nycticorax nycticorax hoactli). There are more 'auku'u seen at this site then any other including Waipi'o. The habitat for the 'auku'u is inland water ponds and lo'i. Along with the 'auku'u are the 'alae (gallinula chloropus sandvicensis) and the commonly known Hawaiian stilt, the ae'o (Himantopus mexicanus knudseni). The birds have found a new habitat in the wastewater project.

Cultural Sites

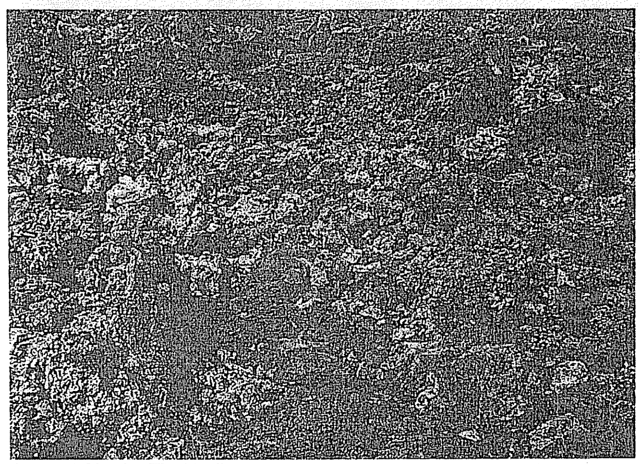
Kealakehe ahupua'a has survived the heavy large-scale development as seen in the southern ahupua'a from Lanihau to Keauhou. These ahupua'a are a micro-megalopolis of continuous hotels, beach houses, condos and subdivisions. Little clues are left of a older civilization where the natural world dictated life. These ahupua'a to the south had some of the more impressive cultural sites that have given way to a new lifestyle.

Kealakehe's cultural sites are not substantial but they do exist. As was mentioned earlier, Hale o Lono is the most meaningful cultural site in Kealakehe. It is the

icon of reciprocity and lokahi stemming from the older society's life way. It was probably the largest man made cultural structure built in the Kealakehe ahupua'a.

Trail System

The project site has a trail system that indicates the passing through of pedestrians from one major site to another. The maps show evidence of the trail coming from Lanihau and heading towards the ponds of Honokohauiki. Trails were the bloodline from one kulana kauhala (village) to the next and usually revealed the rest stop, popular villages, water locations, farming mounds, etc. The trail at the project does not seem to reveal any of these kinds of popular sites.



Cultural Site 1 – The Trail

Cultural Site 2 – The Trail

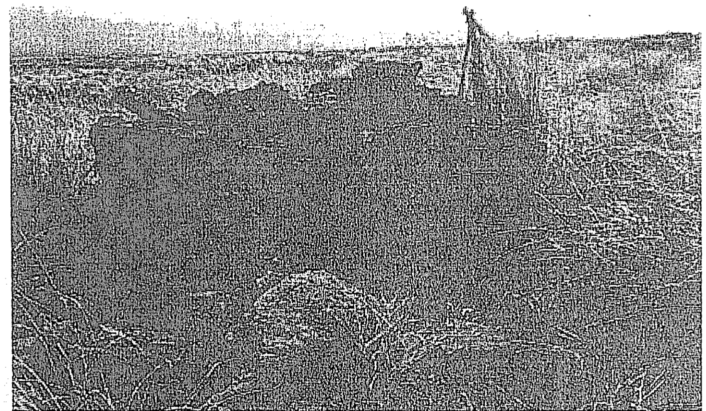
The smooth rocks of the trail revealed themselves when the rough rocks were cleared.

Ahu

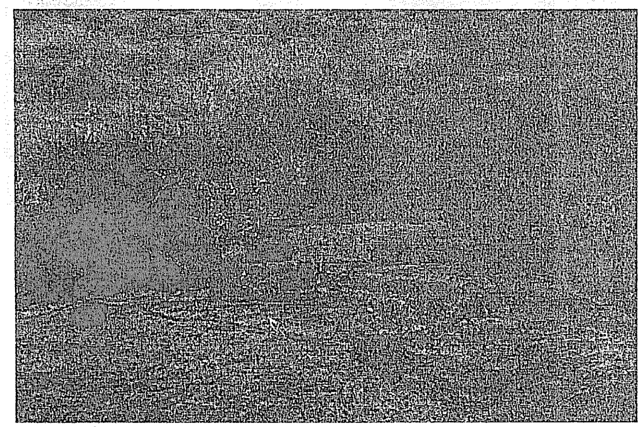
The largest cultural structures found on site are the ahu (small rock cairns). The ahu still intact is located towards the ma kai boundary. This ahu is approximately 40" X 40" square. An ahu was constructed to mark a boundary, bring attention to a location, to place offerings to an occupational deity, to collect water or place articles to be kept for the next time you return. Other ahu have fallen apart after disuse or disassembled.

Ahu used for deity was called kua ahu or kuahu. Kuahu are used indoors or out and were made of rock or wood. The indoor kuahu occupies space in a hula hālau to house hula plants which are manifestations of the deity. The "hale mua", a place of worship for men house is another example of an indoor kuahu. An outdoor kuahu, the "unu o Lono", was an informal Lono structure. Fishermen at the ocean or forest gatherers in the mountain used this same kind of kuahu. These were crude ahu quickly put together to serve the user at a given time.

CS 3 is a well shaped and preserved ahu found toward the ma kai end of the project. Other ahu on the site were not as well preserved and were at different stages of deterioration. Not all the ahu were made in the same shape as CS 3, some were oval with other structures attached to it. Others had only stone alignment, which barely revealed its original shape.



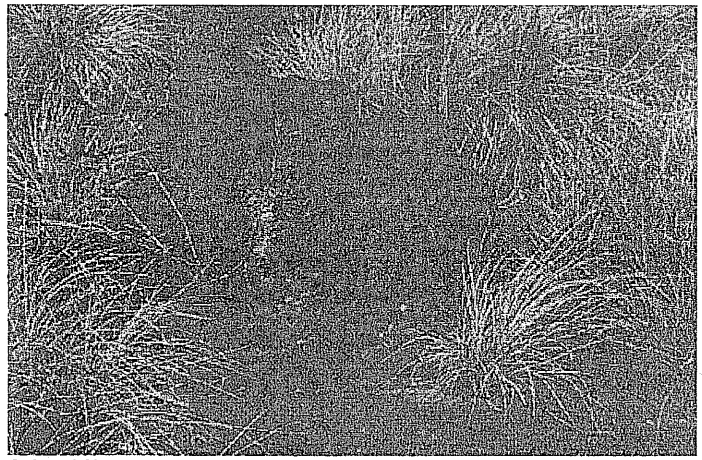
Cultural Site 3 – Ahu



Cultural Site 4 - Ahu

Kealakahē, Burials

Kealakahē with the kahakō (macron) over the final vowel, lends a warning of the possibility of grave sites in the ahupuaʻa. The land space of the project area is relatively manageable for a pedestrian survey and we visited the four times. We carved out sections then walked through each section carefully looking for signs of possible burials. There were many rocks piled in two definite formations scattered throughout the site. The formations were 1) piled on each other horizontally, 2) some were horizontal and others vertical. None of these rock formations seemed familiar, nevertheless they were made by some one for some reason.



Cultural Site 5 – Horizontal vertical formation

We located an empty open vault which had familiar burial patterns. The cap stones of the open vault was laid on the side and the rocks aligning the hole were still in place. It looked like it may have had two cap stones with dirt to hold it in place. The open vault was clean with some grass growing in it however no rock had fallen or thrown in. There were no signs of visible bones. The area around it looked like it might have some other possible sites however we didn't have the tools to search for bones. The ahu at this site did not correlate with burial practices.

Cultural Site 6 – Possible burial site

Cultural Site 7 – Possible burial site

Ocean Quality and Activities

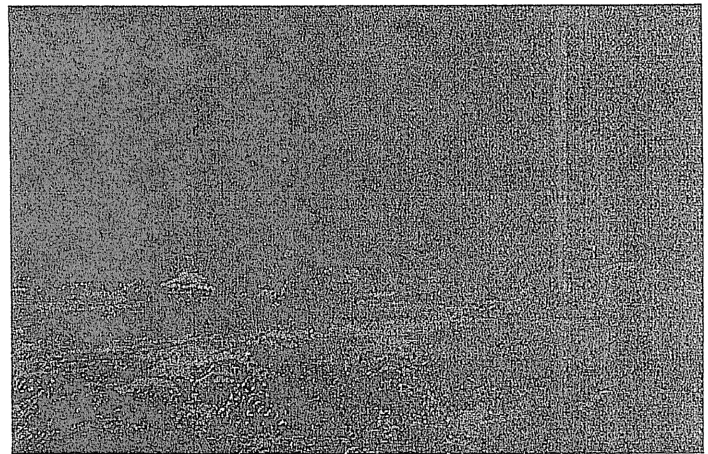
A young local man from Kona did the observation of ocean quality and productivity. He surfs and dives for fish from Keahuolū to Kalāoa, he is familiar with this coast . Two divers were used for this task and they choose to stay within the ʻAlula Bay area, which directly fronts the project site. The mouth of Honokohau Harbor has both niuhi (tiger) and manō-kihikihi (hammerhead) sharks which were a concern for the divers.

The ocean appear to be productive and the water clear except for the area with the underwater moorings. The observation of coral heads appear healthier in the southern bay area of ʻAlula. There are three underwater moorings close to each other on a decline to the deeper ocean.

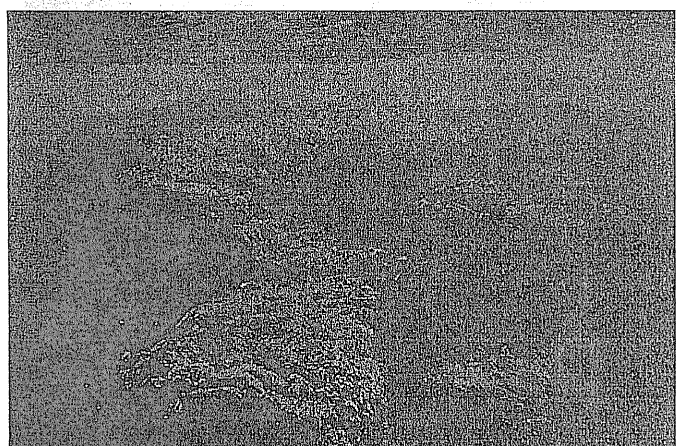
There were schools of wekeʻula (Mulloidichthys vanicolensis). Wekeʻula translates as red weke however the fish has a yellow effect when in the water and only red after it is out of the water. This type of weke is delicious and seems to be in abundant at the three to five inch size. Another good eating fish found there is the mū (Monotaxis grandoculus). Its common name is bigeyed emperor fish. They were found around the underwater mooring and always outside of camara view. The mū are "people smart" and avoid divers and snorkelers. Manini (Acanthurus triostegus), kole (Ctenochaetus strigosus), palani (Acanthurus dussumieri) and pualu (Acanthurus xanthopterus) are plentiful in the bay and are all species of surgeonfish.

The divers did not find the ʻopelu koʻa in ʻAlula bay, instead there were the three underwater mooring and two above water buoys.

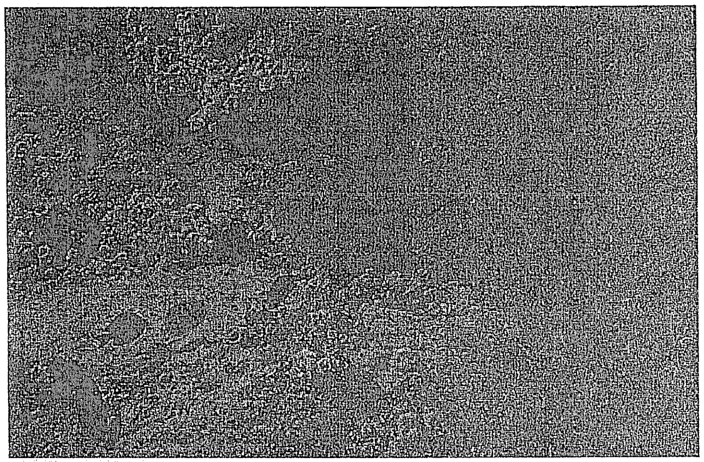
Under Water 1 – Coral in 20 feet of water

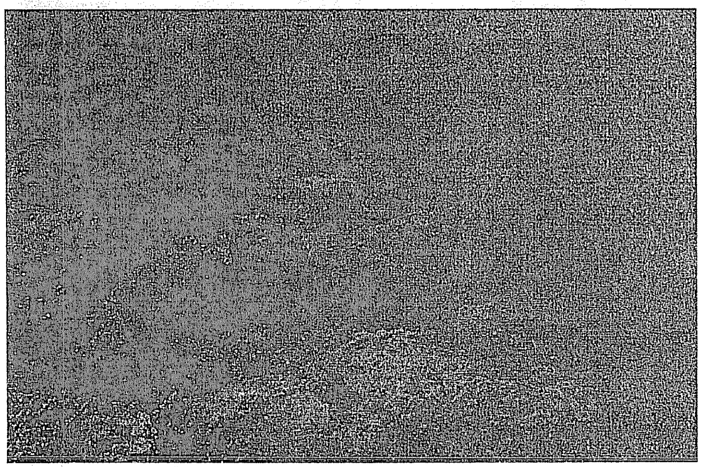


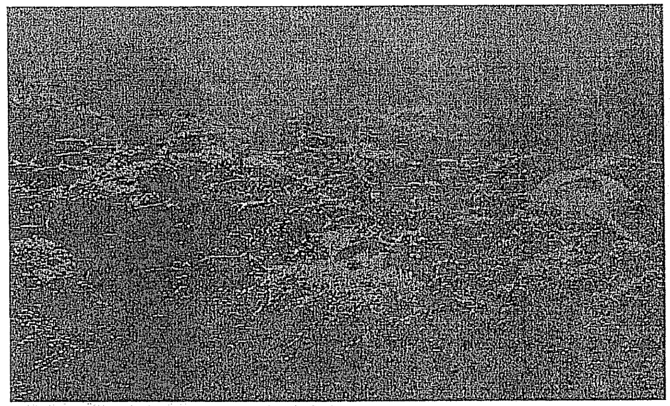
Under Water 2 – Coral in 10 feet of water with



Under Water 3 – Reef 1 foot from the surface


Under Water 4 – Kole and Manini in 25 feet of water


Under Water 5 – Middle of the bay, 25 to 30 feet of water.


Under Water 6 – South point of ‘Alula bay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Under Water 7 – One of three underwater moorings in about 40 feet of water

Under Water 8 – Middle of ʻAlula Bay facing the beach

Interviews

Peter Keka

He is a kamaʻaina of Kona who was raised in the north Kona coast. He is in his sixties and works for Kaloko Honokohau National Park. He builds Hawaiian stone walls. Mr. Keka was knowledgeable in the cultural practices of this area. Mr. Keka is a fisherman and is acquainted with the fishing koʻa (fishing ground) in this area.

Mr. Keka's comments on Kealakehe and how it should be treated are noted below.

1. ʻAlula (or earlier known as ʻAulaula) is the beach that fronts Kealakehe.
2. ʻAiʻopio is the fresh water pond ma uka of ʻAlula, these ponds were sources for ʻopaeʻula used for ʻopelu maunu.
3. Maliu Point was earlier known as Puʻuoina
   House foundations still remain there.
4. Hale o Lono Heiau is north of the beach as you descend to the beach from Puʻuoina, it is the large stone structure on the beach.
5. The Hale o Lono guards were as big as the large rocks at the heiau
6. The Lono family were the caretakers of the heiau area and are no longer there.
7. Point Noio is south of ʻAlula
8. Mr. Keka didn't know the function of the two structures at the point south of ʻAlula.
9. Mr. Keka referenced a Hale o Mono to the north of Hale o Lono and did not know it's function, he thought it was a female heiau as opposed to the maleness of Hale o Lono.
10. He talked of John Mano as a senior kamaʻaina of his whom he learned a lot of history from. Mr. Mano was with the original Kaiʻopua Canoe Club.
11. I asked Mr. Keka about the name Laʻiopua Homestead. He said it should be pronounced Laʻī o pua because there were a lot of Laʻī there and it was out standing when it seeded then went into flower and also when it was yellow.
12. Kaukauholo is the beach and cliff area of Keahuolū ahupuaʻa.
13. Hale Laʻī o Hiʻiaka is synonymous with Hiʻiakanoholae and Keahuolū Point.
14. He also noted that the small ahu, Puʻukaloa, is near a guava tree in Keahuolū.
15. In the Keahuolū ahupuaʻa is Hale o Paoʻo, Pāwai and Papawai which he look at as being different locations. Papawai, he said, is the flat area ma uka of Makaeau rock out side of the old airport which was made of red cinders.
16. Kaʻiwi Point marks the boundary between Kealakehe and Keahuolū ahupuaʻas and at one time there were a lot of pili grass there.
17. Puʻuhulu is in ʻOʻoma and Kawahiwaʻa is the point of ʻOʻoma.
18. He said that people did not live in the project site, but he knew that people lived at the ocean side near Hale o Lono and ma uka of ʻAlula Beach but not inland.

His concerns, non-concerns and suggestions:

a) Concerns – traffic would be congested because of the commercial industrial.

b) Non-concerns – He thinks a wastewater treatment plant is valuable in that area and feels there are new methods of treatment that would not filter into the ground or not have the odor associated with wastewater treatment plants.
c) Suggestions - 1) a playground is needed like a mini play park with rides. 2) the beach should be part of the play park or zigzag running/walking trails.

Michael Ikeda

Michael Ikeda works with Queen Lili'uokalani Trust in the ahupua'a of Keahuolū. He is originally from Honolulu and lived in Kona for approximately 30 years. I interviewed Mr. Ikeda because he has been a neighbor of Kealakehe for many years. The important interview points are listed below.

1. Michael was most concerned with the water quality of the ocean if the wastewater treatment was forthcoming.
2. He was concerned also about the large tourist boats that anchor off shore in the areas where fishing ko'a were noted.
3. Fishing balls or schools are not as prominent as they were when he first arrived here and he attributes their scarcity to too many boats near the feeding areas and too many structures on the ocean side. Preservation is not a consideration.
4. Michael pointed out the areas near shore which still houses the lobsters, aholehole, mamamo and 'opelu from Kealakehe to Keahuolū.
5. I asked Michael about the existing wastewater system and the possible stench that it produced, he was seldom bothered by the smell from the next ahupua'a
6. Micheal introduced me to Peter Keka. He looks to Peter Keka as his mentor for this coast.

Mahealani Pai

Mahealani is a kama'aina of Kona. They also lived in different areas around Hawai'i however Kona is home. Mahealani is well acquainted with the fishing ko'a and fishing style of this area. Preservation of fishing ko'a for the sake of sustaining a lifestyle is foremost in his mind and heart. Mahealani, like Peter Keka and Micheal, continue their fishing and taking care of this part of the coast line.

1. Hale Manō is a shark heiau near the opening of the Honokohau Harbor. I don't know if its still there. Two sharks frequent the area in these times. Hi'upelu moves from this shark hole to the north. The other shark is Papakonāne, who is a tiger shark and it moves toward the south.
2. I don't know the name of the fresh water pond ma uka of 'Alula beach. I don't remember hearing the name or using it for any reason.
3. Before, 'Alula was called 'Aulaula but now everybody just call it 'Alula.
4. I know that there was an 'opelu ko'a in that bay but we didn't fish there. We mostly fish at Honokohauiki and Honokohau and sometimes at Kohanaiki
5. I think that the Waste Water plant does leak. Once in a while there is long growth on the limu and all the brackish limu turns green I think its because of the Waste Water plant.
6. The thing I fear is the continuous building on the coast will affect the quality and quantity of fish caught along this coast. The building of industrials will also affect the ocean water quality.
7. I don't know anything about the kinds of activity at Kealakehe except for the ma uka area where they had some kauila trees and they used the wood of this tree as fishing implements. The story of Kalualapauila and Kaiwi is interesting because of the uila part of that name and I compare it to the Kauila in the uplands.

Elaine Watai

Elaine lives in the ma uka area known as the Jack Hall Housing. Elaine, along with other community and residents of the Kona district formed an association known as Kealakehe Ahupua'a 2000 (KEA2). They are focusing on improving and controlling the Kealakehe Ahupua'a. The ahupua'a system is a Hawaiian cultural/tax land division observed by the indigenous ali'i and konohiki social order. KEA2's vision is to revive the ma uka /ma kai trails providing the whole ahupua'a effect for those living in Kealakehe. Their plans also include a walking / bicycle park near the ocean using the waste water cycle to green that ma kai area.

.KEA2 is concerned with more positive environmental effects on the ma uka area. The ma uka area consists of the new Kealakehe High School, La'i o Pua subdivision and the Jack Hall housing. The smell from the wastewater system and the fumes from the old refuse station directly affect the ma uka area. Developing the ahupua'a to keep an open, healthy, ma kai space was their plan with the community, schools and greater Kona in helping towards this noble task from which they all benefit. KEA 2 is focusing on the present and the future. They did not have the funds needed at this time to accomplish their goals.

Kepa Maly

Mr. Kepa Maly was responsible for the CIA of "Nā Honokohau" for Lanihau Partners and was gracious in providing insight into the Kealakehe ahupua'a in relationship to information of the Honokuhau iki / nui, Keahuolū and Kohanaiki.

Angel & Nita Pilago

Mr. and Mrs. Pilago left O'ahu many years ago hoping to find an ideal place to raise their children and they found it in Kona. They are active residents of Kona and were instrumental in the PASH decision. They formed a non-profit group known as "Friends of Kohanaiki". They fish, surf and have made a double hull canoe. Their children are also active in maintaining the integrity of their immediate coastline. Mr. Angel Pilago was interested in maintaining the quality of ocean water in Kealakehe especially with an Industrial/Commercial Park ma kai of the main highway. He is aware of Kona's growth and the services needed to accommodate that growth. Mr. Pilago is not comfortable about bulldozing the culture sites on the property.

I described some of the cultural sites found in the project area, he commented that the size or significance didn't matter. The site was important because it was there and someone constructed it for a reason and it is a learning tool for us today.

David Roy and Mikihala Roy

Mr. Roy and Ms. Roy, his daughter, are serving as Commissioners for Kaloko/Honokohau's National Park. There are several points of concern they want addressed. Mr. Roy worries about the quality of the underground water. He is very concerned with commercial industry's incapability of containing leakage of waste products. This will be detrimental to the underground water and eventually to the oceanfront and fresh water ponds. When and if there is assurance of a leak proof system that has been tried and proven worthy of maintaining clean water, then his fear of polluted fresh and ocean water will be put at ease. His concern is heightened by another plan for an industrial plant north of Kaloko/ Honokohau's boundary. Both Mr. Roy and his daughter want to be kept abreast of the DHHL's development of Kealakehe ma kai project site.

Recommendations

1. **Provide assurance of maintaining water quality for both ground and ocean with proof that this development will not be responsible for pollution.**

   The interviewees all shared the same sentiment and genuine concern for water quality. Whether the development intended for a Wastewater Plant, Light or Heavy Commercial/Industrial use, they expressed the need for productive ocean life which clean ocean can insure. Three interviewees who fish along the shore of Kekahawai'ole, fish for subsistence and the means of maintaining a lifestyle that is natural to that coast.

2. **Provide assistance to the concept of the "walking trail and bicycle park" ma kai of the project site, which is State Land.**

   Two of the interviewees expressed the concept of a park needed by the population of Kealakehe in maintaining the Kealakehe ahupua'a ma uka / ma kai practice of a self-contained land section. It is the thought of having an ahupua'a where people play, get food and live. This would add greatly to the idea of the holistic community.

3. **Preserve the ahu near the ma kai end of the site and also short section of old walking trail as a symbol of the trail system.**

Conclusion

The cultural impact of the proposed site of Kealakehe will include minor structures, most of which are very small ahu made with less then twelve rocks piled in asymmetric shape. It is curious because there were several of these ahu. The real impact is the land itself and the possible pollution of the coral beds. The land is pahoehoe, in some areas, the pahoehoe layer is thin with dirt under it. This layer of pahoehoe and dirt is ideal for burial sites and ideal for planting sweet potato. Kealakehe is a land with some soil, a few native and Polynesian introduced plants, the ocean fronting the site has coral, fish and fresh water. All the elementary forms to sustain life as suggested in the Kumulipo exist here at Kealakehe ma kai, which consist of the project site and the State land fronting the project extending to the ocean.

The substantial structural culture sites are on State land, which are Hale o Lono and Hale o Kāne. The Native Hawaiian nature deities attached to Kealakehe ma kai are Pelehonuamea, Hi'iakaike'ale'ī, Hi'iakaike'alemoe and Hi'iakanoholae. These deities are associated with Kaiwi Point land feature. Lono is the deity of Hale o Lono. Hale o Kāne nomenclature was given to honor and chum the god Kāne for his manifestations. These are impressive deities for a small part of a small land section. Hale Manō is also located in this same ahupua'a on the north side of the entrance to the harbor.

The common thread through the interview process was water quality. The interviewees only want to be assured that the ground water will not be polluted. Convincing them of this fact will also insure the public's satisfaction. The interviewees were aware of Kona's growing population and Kona's need for services. Although the Wastewater project was initially repelling, they commented on the necessity of this service.

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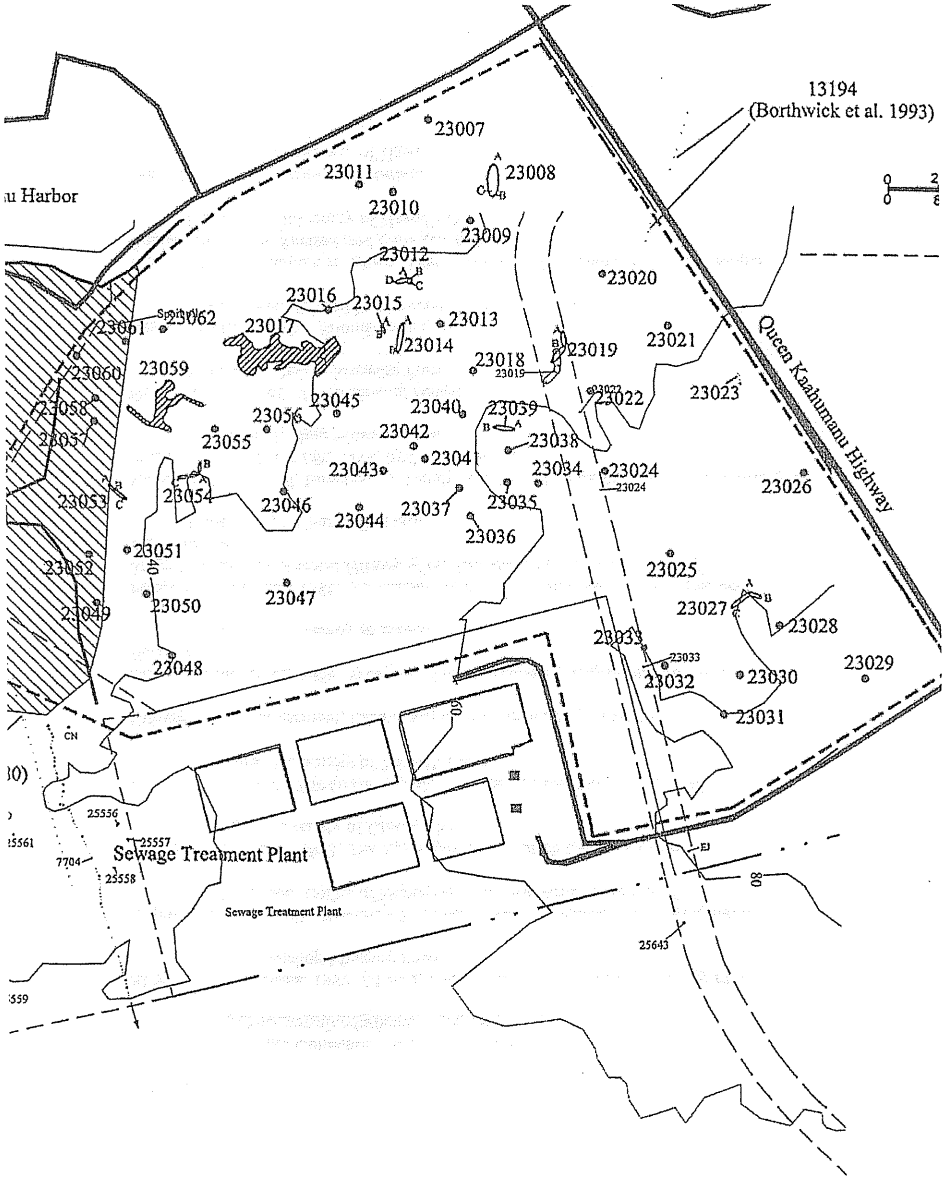
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